REVIEW

OF THE

American Standard Specifications, Test Pieces, and Methods of Testing Iron and Steel,

ADOPTED BY

Committee No. 1 of American Section of the International Association for Testing Materials,

WITH A

Discussion of the Commercial Methods for the Physical and Chemical Testing of Iron and Steel in Use in the United States,

AND

A Critical Review of Foreign Specifications for Steel Rails,

BY

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AT

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I. Review of the American Standard Specifications, Test Pieces and Methods of Testing Iron and Steel.

A. Introduction.

Specifications governing the chemical and physical properties of iron and steel for specific purposes may very properly be made the subject of international agreement. There are certain general requirements which such international specifications should include, and there is a class of requirements which should be omitted.

International specifications should name the process or processes of manufacture by which the steel for a given purpose shall be made; they should not, however, prescribe the details of the process, as the methods of manufacture, producing a satisfactory product, vary in different countries. They should include limits in certain of the chemical constituents of the steel, particularly phosphorus and sulphur for both acid and basic steel, and they should prescribe limits in all physical properties which materially aid in showing whether the steel is suitable for the purpose intended.

International specifications should also describe the shape, number, and location of the test specimens, and give general methods for determining the physical properties specified; they should also mention how the sample for chemical analysis shall be taken. They should contain clauses governing the required finish and branding of the material, and finally a clause granting the inspector the necessary facilities to carry out the provisions of the specification.

The text of ten specifications, drawn on the above lines, will be found as an appendix to this paper. These ten specifications were framed by Committee No. 1 of the American Section of International Association for Testing Materials, and were adopted by a large majority of the thirty-four members of this Committee. They will be discussed by the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Railway Master Mechanics' Association, the American Institute of Mining Engineers, and other technical societies, and will

be presented by Committee No. 1 for discussion and adoption at the third annual meeting of the American Section to be held in New York on October 25–27, 1900.

Part of the work of the Committee included the tabulation of the existing American specifications, and each sub-committee included the best features of these existing specifications in framing these proposed American standard specifications. The reports of the sub-committees have been discussed at frequent meetings of Committee No. 1 since March 9, 1899, and the final vote on each specification was taken on May 1, 1900, by letter ballot of the thirty-four members of Committee No. 1.

A list of these ten specifications is as follows:

Steel Castings.
Steel Axles.
Steel Forgings.
Steel Tires.
Steel Rails.
Steel Splice Bars.
Structural Steel for Buildings.
Structural Steel for Bridges and Ships.
Open-hearth Boiler Plate and Rivet Steel.
Wrought Iron.

The requirements contained in the nine specifications for steel are described and discussed in the following paper under the uniform headings found in each specification, a plan which will materially aid in their comparative study. The specification for wrought iron is referred to independently.

These ten specifications are presented at this International Congress on Methods of Testing Materials of Construction, with the recommendation that, as they are being very generally discussed in America, they also be studied and discussed by this Congress, with a view to their future adoption, as a basis for International Standard Specifications.

B. The Processes of Manufacture Specified.

Crucible Steel.

1. The specifications include the use of crucible steel in the case of forgings, castings, and tires. In the actual American practice of to-day, however, only a very small percentage of these products are made by this process; for instance, the production of crucible steel castings in 1899 amounted

to only 3500 gross tons, and less than 2% of American tires are now made of crucible steel.

Bessemer Steel.

2. A review of the nine steel specifications in the Appendix shows that Bessemer steel may be used for the manufacture of rails, splice bars, and structural steel for buildings including the rivets. It is also specified that castings, axles, and forgings may be made of Bessemer steel.

In American practice of to-day Bessemer steel for the above purposes is made entirely by the acid process.[1]

Practically all the steel rails rolled in the United States are made of Bessemer steel. The total production of all kinds of rails in the United States for 1899 amounted to 2,272,700 gross tons; of this only 523 tons were open-hearth steel rails produced in Pennsylvania and Alabama, and 1592 tons were iron rails. Bessemer steel is used in but a small proportion of the castings, axles, and forgings made in the United States. The production of Bessemer steel castings in 1899 was only 3939 gross tons including the product of one Roberts-Bessemer plant and four Tropenas-Bessemer plants. No statistics are available to show what proportion of the splice bars, and the structural steel for buildings, manufactured in the United States are made of Bessemer steel.

Open-hearth Steel.

3. All of the nine steel specifications allow the use of open-hearth steel, and for boiler plate and rivet steel, structural steel for bridges and ships, and steel axles, it is the only kind of steel specified. No distinction is made between the acid and basic open-hearth process, other than, that in structural steel for bridges and ships a higher phosphorus is allowed in case acid steel is furnished (0.08% instead of 0.06%).

The following official statistics show the recent increase in the adoption of basic open-hearth steel in the United States.

TABLE I. PRODUCTION OF OPEN-HEARTH STEEL IN THE UNITED STATES.

Metric Tons.

Year.	Basic.	Acid.	Total.	Per cent. Basic.
1896	788,721	530,833	1,319,554	59.8
1897	1,073,000	561,502	1,634,502	65.6
1898	1,594,613	671,492	2,266,105	70.4
1899	2,113,832	880,810	2,994,642	70.6

[1] There are three basic-Bessemer plants in the United States, one at Troy, N. Y., one at Pottstown, Pa., and one at Indianapolis, Indiana. None of these plants are in operation.

The processes of manufacture called for in the nine steel specifications are conveniently shown by the following statement.

Specification for	Open-hearth process.	Crucible process.	Bessemer process.
Steel castings	Open-hearth	Crucible	Bessemer
Steel axles	Open-hearth	......	......
Steel forgings	Open-hearth	Crucible	Bessemer
Steel tires	Open-hearth	Crucible	......
Steel rails	Open-hearth	......	Bessemer
Steel splice bars	Open-hearth	......	Bessemer
Structural steel for buildings	Open-hearth	......	Bessemer
Structural steel for bridges and ships	Open-hearth	......	......
O.H. boiler plate and rivet steel	Open-hearth	......	......

Details of Processes Should Not Be Specified.

4. With one exception the specifications for steel quoted in the Appendix very properly omit all restrictions as to *details* of the processes of manufacture, partly because they are offered as international specifications and processes necessarily vary in different countries, and also because it is, in general, outside of the province of the engineer to specify details of metallurgical processes when he is afforded by the manufacturer every reasonable facility to satisfy himself whether or not the finished material is in accordance with the specification. The following clause from the specification for steel rails constitutes the exception above referred to:

"The entire process of manufacture and testing shall be in accordance with the best current practice, special care being given to the following instructions. Ingots shall be kept in a vertical position in pit heating furnaces; no bled ingots shall be used; sufficient material shall be discarded from the top of the ingot to insure sound rails."

As far as American practice is concerned, this clause is unnecessary as the details of the process specified are carried out in the every-day practice of every rail mill in the United States.

If an engineer prefers acid rather than basic open-hearth steel, it is perfectly proper for him to so specify. Of course he restricts competition and increases the cost of his structure. If he desires the finished material annealed, it is also proper for him to so define the process of annealing, that it shall not include a slow cooling from the initial temperature of casting or rolling or forging. It is, however, plainly outside of the territory over which he has jurisdiction for him to require, for instance, that,

"All steel for wire shall be made in an open-hearth furnace lined with silica. This steel shall be made entirely from pig iron, without the admixture of scrap of any kind or form and without the use of any other stock. During the reduction of the steel in the open-hearth furnace, it shall not be decarbonized below 0.10 of one per cent. The finished steel shall be made into bottom cast ingots, not larger than 16 inches square in greatest cross section, weighing not more than 5000 pounds each, and cast in groups of not less than six ingots to each group.

"No steel shall be made or cast unless the engineer or his representative is present. All superintendents, foremen, melters, helpers and others engaged in the manufacture of the steel for this work shall be men experienced in this line of work, and of sufficiently recent practice to insure the best results."

It is the concensus of opinion among steel manufacturers, who are certainly in a position to be the best judges in the matter, that in actual practice, requirements such as those quoted above, fail in obtaining any better material than is furnished on specifications in which they do not occur. There is therefore no valid reason for their existence. Conscientious inspection, under specifications governing the details of nearly every step in the manufacture is utterly impossible, within the cost of inspection allowed by the engineer or contractor. Even if the one or two inspectors sent to the steel works are *thoroughly* familiar with the process of manufacture, which is seldom the case, it would be impossible for them to be present and pass intelligent judgment on all the various steps of the process and also inspect and superintend the testing of the finished product, without very materially delaying manufacturing operations. The requirements of a specification governing the details of the process of manufacture are therefore often openly ignored by both manufacturer and inspector, and in some cases are withdrawn or materially modified by the engineer to enable his contractor to place the order for the material.

Annealing.

5. Reference to this important process for the removal of the internal strains unavoidably present in such finished material as steel castings, steel forgings, eye-bars, and plates, has been, to a large extent, omitted in the steel specifications under discussion, so as to leave the customer free to add it to the requirements called for, if he desires a better material and is willing to pay the additional cost; or free to definitely specify that his material shall *not* be annealed in case he fears, as is unjustly

claimed by some engineers, that the annealing process will be used by the manufacturer to bring an inferior material within the physical requirements specified. As before stated it is perfectly proper for the engineer to specify that slow cooling from the initial temperature of casting, rolling, or forging, shall not be considered annealing, for such a cheap substitute for true annealing enlarges the grain and therefore weakens the steel. Further than this, however, it is better for him to increase the required percentages of elongation and contraction of area than to attempt to specify the temperature to which the steel shall be reheated, or other details of the annealing process.

C. The Chemical Properties Specified.

Chemical Requirements.

6. Table II gives the chemical requirements to which steel must conform when used for the nine different purposes specified in the Appendix. Where tensile strength is specified, limits in carbon have been purposely omitted, except in the case of splice bars, where a carbon limit is included for the reason that the specified physical properties are seldom actually called for. Limits in manganese are included in the case of tires, boiler plate and rivet steel, splice bars and rails, and silicon only in the case of tires and rails. Phosphorus is very properly specified in all the different classes included in the nine steel specifications, and sulphur in all but rail steel, and structural steel for buildings. No limit in copper has been specified, as it has been conclusively proved[1] that it exercises no deleterious influence even when present in greater proportions than found in the steel made in certain localities in the United States partly dependent on ores carrying small quantities of this ingredient.

Carbon not Specified.

7. The omission of carbon when tensile strength is specified is in accordance with the latest and best views on this subject. Instances might easily be cited from existing specifications, where the tensile strength specified could not be met, if the required limits in carbon, and in some cases manganese and silicon, were adhered to in the selection of the steel. Where the physical properties desired are clearly and properly

[1] H. H. Campbell's Manufacture and Properties of Structural Steel. New York, 1896, pp. 274–5.
Copper in Steel, by Albert Ladd Colby. The Iron Age Vol. 64, Nov. 30, 1899, pp. 1–7.

TABLE II.—REQUIRED LIMITS IN THE CHEMICAL COMPOSITION OF STEEL.

	Specification for	Carbon. Per cent.	Manganese. Per cent.	Silicon. Per cent.	Phosphorus Not over Per cent.	Sulphur. Not over Per cent.	Nickel. Not over Per cent.
Steel Castings	Ordinary Castings	Not over .40	—	—	.08	—	—
	Tested Castings	—	—	—	.05	.05	—
Steel Axles	Car, Engine Truck and Tender Truck	—	—	—	.06	.06	—
	Driving Wheel (Carbon Steel)	—	—	—	.06	.06	—
	Driving Wheel (Nickel Steel)	—	—	—	.04	.04	3.75
Steel Forgings	Of Soft or Low Carbon Steel	—	—	—	.10	.10	—
	Of Carbon Steel, not Annealed	—	—	—	.06	.06	—
	Of Carbon Steel, Oil-Tempered or Annealed	—	—	—	.04	.04	—
	Of Nickel Steel, Oil-Tempered or Annealed	—	—	—	.04	.04	3.75
Steel Tires		—	Not over .80	Not under .20	.05	.05	—
Structural Steel for Buildings, including Rivets		—	—	—	.10	—	—
Structural Steel for Bridges and Ships, including Rivets	Acid Open-Hearth	—	—	—	.08	.06	—
	Basic Open-Hearth	—	—	—	.06	.06	—
Open-Hearth Boiler Plate and Rivet Steel	Flange or Boiler Steel	—	.30–.60	—	.06	.05	—
	Fire Box Steel	—	.30–.50	—	.04	.04	—
	Extra Soft Steel	—	.30.–50	—	.04	.04	—
Steel Splice Bars		Not over .15	.30–.60	—	.10	—	—
Steel Rails, of Weight per Yard Specified	50 lbs. to 59 + lbs	.35–.45	.70–1.00	.20	.10	—	—
	60 " " 69 + "	.38–.48	.70–1.00	.20	.10	—	—
	70 " " 79 + "	.40–.50	.75–1.05	.20	.10	—	—
	80 " " 89 + "	.43–.53	.80–1.10	.20	.10	—	—
	90 " " 100 "	.45–.55	.80–1.10	.20	.10	—	—

specified, the chemistry of the steel other than prescribing the limits of the injurious impurities, phosphorus and sulphur, may, in the present state of the art of making steel, be safely left to the manufacturer.

For a discussion of methods of sampling and methods for chemical analysis see paragraphs 29 and 30, pages 25–28.

D. THE PHYSICAL PROPERTIES SPECIFIED.

Tensile Strength.

8. In all the specifications except for steel rails, limits in tensile strength are specified. For the structural steels, boiler plate and rivet steel, and splice bars a range in tensile strength of ten thousand pounds per square inch is specified as shown in Table III. In all other specifications minimum requirements are given. The tensile tests required on full sized eye-bars are given in the specification for structural steel for bridges and ships.

Tensile strength is specified in order to insure the necessary strength in the material. The elastic limit is, however, the true index of resistance to working stresses. In material uniformly heated before rolling, a large number of tests have proved that the elastic limit practically never falls below fifty per cent. (50%) of the tensile strength. As its accurate determination is an impossibility in rapid commercial testing, the tensile strength is relied upon to indicate the elastic limit, with which information the stresses which may be successfully carried can be safely computed.

The yield point as determined in commercial testing furnishes a desirable check on the accuracy of the assumption that the elastic limit of the material under consideration is at least one-half the tensile strength.

Yield Point and Elastic Limit.

9. As shown in Table III the yield point is required wherever tensile strength is specified except in the case of steel tires. By reference to the specification for steel forgings it will be found that in annealed and oil-tempered carbon steel and nickel steel forgings, elastic limit is called for instead of yield point.

Elongation.

10. The percentage of elongation required, is measured in eight inches in the structural steels, boiler plate and rivet steel, and splice bars, and in two inches in castings, axles, forgings, and tires. The required percentages of elong-

TABLE III.—REQUIRED LIMITS IN THE PHYSICAL PROPERTIES OF STEEL.

Specification for		Tensile strength. Pounds per square inch.	Yield-point. Pounds per square inch.	Elongation. See Note (e). Per cent.	Contraction of area. Per cent.	Bending test. D=Diameter. T=Thickness.
Steel Castings	Ordinary Castings	——	——	—	—	——
	Tested Castings, Hard	85,000	38,250	15	20	——
	Tested Castings, Medium	70,000	31,500	18	25	90° D = 2T
	Tested Castings, Soft	60,000	27,000	22	30	120° D = 2T
Steel Axles	Car, Engine Truck and Tender Truck	——	——	—	—	——
	Driving Axles (Carbon Steel)	80,000	40,000	18	—	——
	Driving Axles (Nickel Steel)	80,000	50,000	25	45	——
Steel Forgings	Soft or Low Carbon Steel	58,000	29,000	28	35	180° D = T
	Carbon Steel, not Annealed	75,000	37,500	18	30	180° D = 3T
	Carbon Steel, Annealed	See specifications. Physical qualities vary with the diameter of Forgings. See Note (c).				
	Carbon Steel, Oil-tempered					
	Nickel Steel, Annealed					
	Nickel Steel, Oil-tempered					
Steel Tires	Passenger Engines	100,000	——	12	—	——
	Freight Engines and Car Wheels	110,000	——	10	—	——
	Switching Engines	120,000	——	8	—	——
Structural Steel for Buildings	Rivet Steel	50–60,000	30,000	26	—	180° Flat
	Medium Steel	60–70,000	35,000	22	—	180° D = T
				See Note (b)		
Structural Steel for Bridges and Ships	Rivet Steel	50–60,000	30,000	26	—	180° Flat
	Soft Steel	52–62,000	32,000	25	—	180° Flat
	Medium Steel	60–70,000	35,000	22	—	180° D = T
				See Note (b)		
Open-Hearth Boiler Plate and Rivet Steel	Flange or Boiler Steel	55–65,000	33,000	25	—	180° Flat
	Fire Box Steel	52–62,000	32,000	26	—	180° Flat
	Extra Soft Steel	45–55,000	30,000	28	—	180° Flat
				See Note (b)		See Note (d)
Steel Rails (See Note a)		——	——	—	—	——
Steel Splice Bars		54–64,000	32,000	25	—	180° Flat

Note (a). This table does not include the drop test required on castings, axles, tires, and rails; the homogeneity test for fire-box steel; nor the percussive test for large steel castings.

Note (b). Reference to the text of the specifications must also be made for the variations in elongation allowed for thick and thin structural steels and boiler steel, and for the tensile tests of full-sized eye-bars.

Note (c). In the four classes of steel forgings not tabulated above, it will be found, by reference to the specifications, that elastic limit is specified instead of yield-point.

Note (d). These same bending tests are required after quenching. (See specifications for details.)

Note (e). The elongations given for castings, axles, forgings, and tires are on 2″, the others on 8″ gauged length.

ation are shown in table No. III. In the specifications for structural steel for buildings and for bridges and ships and in boiler plate and rivet steel, certain modifications are noted for thin and thick material and for pins.

Elongation in the large majority of commercial steels is a safe index of ductility. In the present state of the art it is a safe check, where only minimum tensile strength is required, against the use of a steel too high in carbon or other hardening elements, for the purpose intended. The ease with which the determination can be made on rolled material, makes it valuable and desirable in the commercial testing of large output, where rapidity as well as accuracy of testing are demanded.

Contraction of Area.

11. The percentage of contraction of area is included in the requirements for castings, axles, and forgings where the tensile strength is determined on a turned test specimen. It was omitted from the specification for tires, where a turned specimen is also used, because it was considered an unnecessary requirement in testing the high carbon steel used in this case, as the tires are very seldom annealed.

The value of this determination, as an index of the quality of steel, is fully appreciated by those who have made a comparative study of microscopical structure, and the accompanying physical properties as determined on turned specimens. The uniformly fine-grained micro-structure only attained when a proper heat treatment has given to the steel the best physical qualities, is invariably accompanied by the highest percentage of contraction of area obtainable with any given class of steel.

Bending Tests.

12. No bending test is included in the specifications for axles, tires, and rails. The bending tests required in the other six steel specifications are compared in Table III, where the letter "T" denotes the thickness of the bending test specimen, and the letter "D" the diameter of the piece around which it is bent. For open-hearth boiler plate and rivet steel the bending tests given in the table are required after the specimen has been quenched as well as in the natural condition. In all other cases the cold bending tests given in the table are to be made on untreated bending specimens cut from the finished material.

The cold bending test is a valuable indication of the structure of the metal, and in this respect bears a close relation to the contraction of area. The two are indications of the same quality in the steel, namely, its capacity for cold flow. A steel having a high contraction of area will always stand severe cold bending, and, conversely, a steel capable of severe cold bending, will always show high contraction of area. This makes the cold bending test particularly valuable, as an indication of the structure of the metal, in cases where there is any difficulty in obtaining a true and ready measure of the contraction of area.

Drop Tests.

13. The specifications for axles, tires, and rails call for a drop test and in the specification for steel castings it states that a test to destruction may be substituted for a tensile test in the case of small or unimportant castings. None of the other specifications include a drop test.

An axle must stand a certain number of blows at specified heights without rupture and without exceeding, as the result of the first blow, a given deflection. These varying requirements for each diameter of axle are given in the specification. A tire must stand, without breaking or cracking, successive blows from increasing heights until it shows a deflection equal to $D^2 \div (40T^2 + 2D)$ in which "D" is the internal diameter of the tire, and "T" the thickness at center of tread. A rail must not break or crack under a single blow from heights varying with the section of the rail, as shown in detail, in the specification for rails.

The features of the drop testing machines, subject to specification, are referred to in paragraph 26, page 24.

Drop tests were included in the specifications for axles, tires, and rails, as it was fully appreciated by the Committee that materials which will be submitted to shocks when in actual use, should be tested by impact. In each case the drop test adopted is in accordance with general American practice, which after a number of years' experience has been found to give very satisfactory results.

Homogeneity Test.

14. This test is confined to fire-box steel. Its object is to show the uniformity of the metal, that is, freedom from closed or partially welded blow holes, pipe, or slag. A sample taken from a broken tensile specimen, shall not show

any single defective flaw or slag streak more than one-fourth inch (1/4") long in any of the three fractures obtained by carrying out the test as described either in paragraph 27, page 25, or in the text of the specification for open-hearth boiler plate and rivet steel.

Percussive Test.

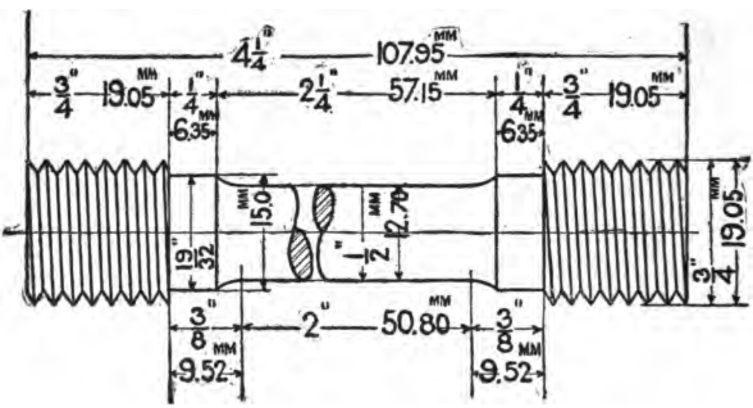
15. This test is only specified for large steel castings. It consists in suspending and hammering the casting at numerous places. The test is made to locate any cracks, flaws, defects or weakness in the casting.

E. The Test Pieces and Methods of Testing Specified.

Tensile Specimens.

16. The standard turned test specimen, one-half inch, (1/2") diameter and two inch (2") gauged length, (see Figure I) is prescribed in the specifications for steel castings, axles, forgings, and tires.

Figure 1.



Much may be said in favor of the general adoption of this test specimen of a gauged length of four diameters, for the commercial testing of these four classes of steel. With axles and all steel forgings a much shorter prolongation of the forging is required for a longitudinal specimen of the above length than for a test specimen of eight inch gauged length. The shorter specimen therefore requires the manufacturer to consign much less good

metal to scrap, an item of considerable importance to the customer in the case of forgings of large diameters.

Furthermore less time and labor is expended in cutting out and machining the shorter test specimen. At a given cost a much better idea of the quality of the metal can therefore be obtained, for several short specimens can be taken at different positions in an important casting or forging at the same cost for preparation, as one long specimen.

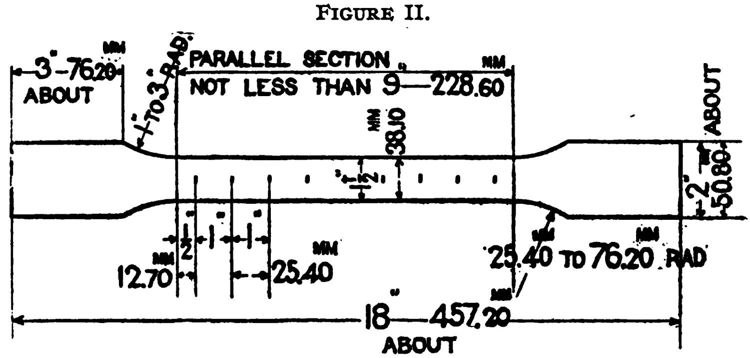
The shorter specimen has also the great advantage of enabling the customer to determine the character of the material at places in a complicated casting or forging where there is not space enough for a longer specimen, as between the webs of crank shafts. In the case of steel tires the shorter specimen is greatly preferable, for when cut from the rim of the tire used for the drop test, the longer specimen can very seldom be obtained unless the tire is heated and straightened, an operation which at once destroys its value as a representative test of the finished tires of the melt.

Finally the physical properties called for in the specifications for steel castings, axles, forgings, and tires can be accurately and readily determined when using the standard test specimen recommended. For in cases where elastic limit is specified instead of yield point, an apparatus reading to the one ten-thousandth of an inch (0.0001") can be easily attached and readings readily made. The determination of the tensile strength is not materially affected by the length of the specimen. The percentage of contraction of area and the quality of the fracture, both very important factors in determining the quality of the metal, are shown with equal accuracy and distinctness with the shorter specimen, as with one of greater length. The higher percentages of elongation obtained on two inches are compensated for by having correspondingly higher requirements in the specifications. There are therefore no practical objections to the general adoption of the test specimen shown in Figure I for the commercial testing of these four classes of materials.

For the sheared plates used in structural steel for buildings, structural steel for bridges and ships, and in open-hearth plate steel the specifications call for the standard test specimen of eight

inch (8″) gauged length shown in Figure II. For material other than sheared plates these three specifications provide that the test specimen may be that shown in Figure II or it may be planed or turned parallel throughout its entire length, and in all cases where possible, two opposite sides of the test specimen shall be the rolled surfaces. The three specifications further provide that rivet rounds and small rolled bars shall be tested of full size as rolled. In the specification for splice bars it is not specified whether the test specimen shall be planed parallel or of the shape shown in Figure II. Owing to the shape of the section of splice bars the parallel specimen can be more readily obtained. In all these necessary variations from the shape of specimen shown in Figure II, however, the same gauged length of eight inches (8″) is required.

FIGURE II.



PIECE TO BE OF SAME THICKNESS AS THE PLATE.

The standard test specimen shown in Figure II has already been so generally adopted for the commercial testing of all kinds of sheared plates that argument in its favor is almost superfluous. In the present day of large products of structural and plate steel, the preparation of the many test specimens, without a delay in shipment of finished material, necessitates the adoption of a standard sized specimen which can be rapidly prepared in groups, by special machines, from the coupons from plates of varying thicknesses. The ability to compare the physical properties of different makes of such a wide variety of steel, made possible by the use

of the standard test specimen, forms the strongest argument in favor of its general adoption.

Number of Tensile Specimens.

17. In the specifications for driving axles, tires, structural steel for buildings, structural steel for bridges and ships, and splice bars, one tensile specimen from each melt or blow, as the case may be, is recommended. With open-hearth plate and rivet steel one specimen is taken from each plate as rolled, and two from each melt of rivet rounds. The specifications for castings and for forgings state that the number of tensile specimens shall depend upon the character and importance of the casting or forging and must therefore be regulated by individual cases.

Location of Tensile Specimens.

18. The specifications for structural steel for buildings, structural steel for bridges and ships, open-hearth plate and rivet steel, and splice bars, contain no instructions as to the location of the tensile specimen. For driving axles and forgings it is provided that the tensile specimen shall be cut longitudinally and that the center of the specimen shall be half way between the center and outside of the axle or forging. When forgings have large ends or collars, the test specimen shall be taken from the prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged hollow or bored, the specimen shall be taken within the finished section prolonged, half way between the inner and outer surface of the wall of the forgings.

With steel castings it is specified that the tensile specimen shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow, or from the sink heads (in case heads of sufficient size are used). With steel tires the specimen shall be cut cold from the tire tested under the drop or if no drop test is required, the test specimen shall be forged from a test ingot cast when pouring the melt; the test ingot receiving, as nearly as possible, the same proportion of reduction as the ingots from which the tires are made.

19. The specification for steel castings states that the coupon or sink head must receive the same treatment as the casting or

Annealing of Tensile Specimens.

castings, before the specimen is cut out, and before the coupon or sink head is removed from the casting. The specifications for structural steel for buildings, and for structural steel for bridges and ships both provide that material which is to be used without annealing or further treatment, shall be tested for tensile strength in the condition in which it comes from the rolls; whereas, with material which is to be annealed or otherwise treated before use, a full-sized section of tensile test specimen length, shall be similarly treated before cutting the tensile test specimen therefrom.

Methods for Tensile Tests.

20. None of the specifications prescribe the methods to be used for the determination of tensile strength, elongation or contraction of area. All of the specifications in which the yield point is included in the prescribed physical properties, state that the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine. In the specification for steel forgings, where elastic limit is required in some cases, it is provided that the elastic limit specified shall be determined by means of an extensometer, which is to be attached to the test specimen in such manner as to show the change in rate of extension under uniform rate of loading, and will be taken at that point where the proportionality changes. The actual every-day practice of American steel works in determining the physical properties of iron and steel is discussed in paragraphs 36–49, pages 30–37.

Test Specimens for Bending.

21. As stated in paragraph No. 12, no bending test is included in the specifications for axles, tires, and rails. It was considered unnecessary to specify the length of the bending specimen in any case. For castings and forgings a specimen one inch (1″) wide by one-half inch (1/2″) thick is specified. With structural steel for buildings and for bridges and ships, and with open-hearth plate and rivet steel, it is specified that the bending specimen shall be one and one-half inches (1-1/2″) wide if possible; and further that with material three-quarters of an inch (3/4″) and less in thickness the specimen shall have the natural rolled surface on two opposite sides, whereas in case of material more than three-quarters of an inch (3/4″) in thickness the specimen may be one-half inch (1/2″)

thick. Each of these three specifications state that bending tests on rivet rounds shall be made on full-sized specimens, as rolled. With splice bars no particular size is specified when the specimen is cut from the head of the splice bar. If preferred, the bending test may be made on an unpunched splice bar which, if necessary, shall be flattened before testing.

Number of Bending Test Specimens.

22. The specifications for structural steel for buildings and for bridges and ships and for splice bars specify that one bending test specimen shall be taken from each melt or blow. For open-hearth plate and rivet steel, one cold bending specimen, and one quenched bending specimen, will be furnished from each plate as rolled, and for rivet rounds two cold bending specimens, and two quenched bending specimens, from each melt. The specifications for castings and forgings state that the number of bending tests will depend upon the character and importance of the casting or forging.

Location of Bending Test Specimens.

23. No special location for the bending test specimen is mentioned in the specifications for structural steel for buildings, for bridges and ships, and for open-hearth plate and rivet steel. For splice bars the specimen may be cut from the head of the splice bar, or if preferred, the bending test may be made on an unpunched splice bar which, if necessary, shall be flattened before testing. When forgings have large ends or collars, the bending test specimen shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged hollow or bored, the specimen shall be taken within the finished section prolonged, half way between the inner and outer surface of the wall of the forging. With steel castings it is specified that the bending test specimen shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow, or from the sink heads (in case heads of sufficient size are used).

Annealing of Bending Test Specimens.

24. The specification for steel castings states that the coupon or sink head must receive the same treatment as the casting or castings, before the bending test specimen is cut out and before the coupon or sink head is removed from the casting. With forgings the bending test is cut

from a prolongation of the finished and treated forging. With splice bars, structural steel for buildings and for bridges and ships, and with open-hearth plate and rivet steel it is specified that the bending test specimen shall be taken from the material as it comes from the rolls, even if the material is to be subsequently annealed which is the case with eye-bars.

Methods for Bending Tests.

25. Each of the six steel specifications in which a bending test is required, contains the following clause ; "the bending test may be made by pressure or by blows." The methods used in American steel works for making bending tests are referred to in paragraph 48, page 35.

Methods for Drop Tests.

26. The drop tests required for axles, tires, rails, and castings are noted in paragraph No. 13. In each case a sample of the finished material ready for shipment, is subjected to the test ; in the case of rails it is specified that the piece tested shall not be more than six feet (6′) long.

In testing axles and tires one is selected from each melt. In testing rails, a piece of rail is selected from every fifth blow with provision for testing intermediate blows in case three rails from the tested blow fail. In steel castings where the drop test, or test to destruction as it is called, is substituted for the tensile test, three castings from a lot are tested, the lot consisting of all the castings from the same melt or blow annealed in the same furnace charge.

Tires are placed vertically under the drop in a running position on a solid foundation of at least ten (10) gross tons in weight and subjected to successive blows from a tup weighing 2240 pounds, falling from increasing heights until the required deflection is obtained. Rails are placed head upwards on solid supports three feet (3′) apart. It is specified that the anvil block shall weigh at least 20,000 pounds and that the supports shall be a part of, or firmly secured to, the anvil. Also that the tup shall weigh two thousand (2000) pounds and that its striking face shall have a radius of not more than five inches (5″). The machines in use in America vary somewhat in other non-essential details.

Axles are placed on supports three feet (3′) apart in such a position that the tup will strike the axle midway between the ends. The anvil must weigh 17,500 pounds, and the tup 1640 pounds ;

the radius of supports and of the striking face of the tup in the direction of the axis of the axle must be five inches (5″). The anvil is supported on twelve helical springs which rest on a cast iron base resting in turn upon a solid foundation. The anvil must be free to move in a vertical direction. Each of the twelve springs has an outside diameter of eight inches (8″) and consists of five coils of a rod 1-3/16″ diameter and seven coils of a rod 13/16″ diameter. The free height of the spring is 9-1/8″ and the height under a load of 6650 pounds, 7″. The construction of this axle testing machine is shown in Figure III. It is in general use in America for testing axles, and is recommended by the Master Car Builders' Association of the United States. The specification for axles gives full details of the method by which the required deflections for the different sized axles shall be measured.

Method for Homogeneity Test.

27. A portion of the broken tensile specimen is used for making the homogeneity test required on fire-box steel. Three transverse grooves about one-sixteenth of an inch (1/16″) deep, are made in the steel either by nicking with a chisel or by means of a machine. The first groove is two inches (2″) from the square end of the specimen, the second two inches (2″) from it on the opposite side, and the third two inches (2″) from the second groove and on the opposite side from it. The test is made by fastening the specimen in the vise firmly with the first groove about one-quarter of an inch (1/4″) above the jaws, and bending it away from the first groove by a number of light blows from a hand hammer until it breaks. It is broken at the other two grooves in the same manner. The required freedom from flaws in these three fractures is described in paragraph 14, page 17.

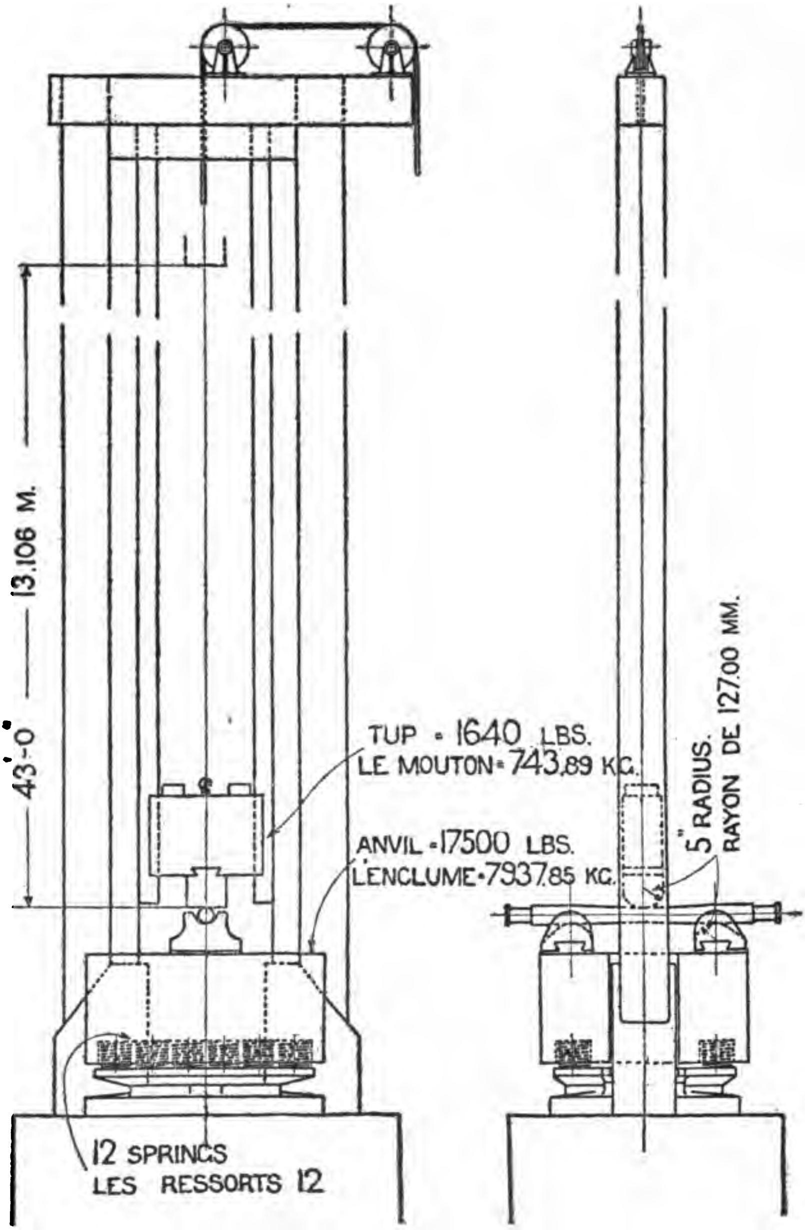
Method for Percussive Test.

28. This test of large steel castings consists simply in suspending and hammering the casting at numerous places to locate the defects as outlined in paragraph 15, page 18.

Samples for Chemical Analysis.

29. Each of the nine steel specifications contains a paragraph defining the location of the drillings or turnings taken to determine whether or not the material conforms to the prescribed chemical requirements. The specifications for structural steel for buildings, structural steel for

FIGURE III.


43'-0" 13.106 M.
TUP = 1640 LBS.
LE MOUTON = 743.89 KG.
ANVIL = 17500 LBS.
L'ENCLUME = 7937.85 KG.
5" RADIUS.
RAYON DE 127.00 MM.
12 SPRINGS
LES RESSORTS 12

bridges and ships, steel splice bars, and steel rails, state that the drillings shall be taken from the small test ingot, cast while pouring the melt or blow. All the other specifications provide that the drillings may be taken from the small test ingot, if preferred by the inspector, but specify other locations as follows:

In the case of castings and forgings, turnings from the tensile specimen or drillings from the bending test specimen may be used. With steel tires, turnings from the tensile specimen or from the tire itself may be used. With steel axles, turnings from the tensile specimen in the case of driving axles is recommended, and longitudinal drillings taken midway between center and outside of the axle in the case of car, engine, and tender truck axles. The specification for open-hearth boiler plate and rivet steel provides, in the case of locomotive fire-box steel, that a check on the analysis of the small test ingot may be made from drillings from the tensile specimen from each plate as rolled; and for other material, from drillings from one tensile specimen from each melt.

In the case of steel rails, splice bars, and the structural steel for buildings, bridges and ships it is proper to limit the analyses to drillings from the test ingot taken when pouring the heat, for a representative average sample of each melt or blow cannot, in these cases, be taken in any other way. No one who has studied the unavoidable variations in chemical composition of the different parts of a section of a rail, for instance the bottom of the flange, the top of the head and the center of the head, will claim that the analysis of drillings from a rail is representative of the heat from which the rail was rolled. Furthermore even with a proper percentage of discard, there is a variation in chemical composition between the rail from the top and from the bottom of the same ingot. The same statements are true of splice bars and of the structural steels.

Even with the test ingot it is necessary to exercise care to avoid segregation and obtain a representative average sample. Whenever the steel shows a decided tendency to rise in the small test ingot molds it is advisable to quiet it by adding a very minute quantity of pure metallic aluminum, for otherwise drillings taken for carbon determination in the vicinity of the blow-holes will give misleading results. It is also advisable to roll or ham-

mer the test ingot into a bar and drill a hole through the bar rather than to obtain the drillings for analysis from the test ingot itself. With these precautions the test ingot may be relied on to furnish a representative average sample of the melt or blow of steel.

Methods for Chemical Analysis.

30. All suggestions as to methods for chemical analysis have been purposely omitted from the specifications under discussion. Entire uniformity in the details of the various analytical methods used in steel works laboratories will probably never be realized, nor is it a necessity in obtaining accurate commercial analyses.[1]

Great credit should be given to the steel works chemist for the success which has attended his earnest efforts to meet the urgent demands made on him for rapid accurate analyses, for he has thereby very materially assisted the steel maker in securing and maintaining uniformity in his product. A brief outline of the methods in most general use for the analysis of steel in American steel works laboratories will be found in section III, pages 37–50.

F. Variation in Weight.

31. The variation in weight permissible in rolling plates is very properly included in the specifications for structural steel for buildings, structural steel for bridges and ships, and open-hearth plate and rivet steel. The overweight is caused by the unavoidable wear of the plate rolls, usually producing a plate slightly thicker in the central part than on the edges. A prescribed standard of excellence in this regard places all manufacturers on equal footing and requires them to keep their plate rolls in good condition. The allowances are based on the assumption that one cubic inch of steel weighs 0.2833 pound and provision is made for plates ordered by weight, and also when ordered to gauge. The prescribed variations are very properly the same in each of the three specifications.

G. Finish.

32. Such a wide variety of finished material is covered in the nine steel specifications under discussion, that a summary of the

[1] The reader is referred to the excellent paper by the Baron Hanns Jüptner von Jonstorff entitled "The Introduction of Standard Methods of Analysis." See Journal of the Iron and Steel Institute, No. 1, 1896, pages 80–138.

clauses contained under this heading is impossible. In each case the requirements are drawn so that only material with a workmanlike finish and freedom from injurious imperfections shall be accepted. In the specification for rails the question of finish is treated under the subdivisions, "section;" "weight," "length," "drilling" and "finish." Second quality or No. 2 rails are also defined.

H. Branding.

33. The marking of finished material is now in general use. It permits the identification and date of manufacture of material which has given exceptionally good or long service or which has failed in service, and is thus a protection and an advertisement for the reputable manufacturer. A review under this heading, of the nine steel specifications, shows that in all cases but castings and forgings, every finished piece must be marked except that small pieces may be shipped in bundles securely wired together with the melt or blow number on a metal tag attached. In the case of rails, besides stamping the blow number on each rail, the name of maker, the month and year of manufacture, must be rolled in raised letters on the side of the web of each rail. In splice bars the name of maker and the year of manufacture must be rolled in raised letters on the side of each splice bar. In axles besides the melt number the initials of the maker must be stamped on each axle; and in tires the maker's brand and number must be stamped on each finished tire.

I. Inspection.

34. Each specification makes ample provision to assure the inspector all facilities necessary for a thorough inspection of the material.

J. Specification for Wrought Iron.

35. It was found impossible to include this specification in the preceding review of the nine steel specifications under the uniform headings found in them all. A separate summary of the physical properties required, and of the test pieces and methods of testing specified is inadvisable, and reference to the full text of the specification, to be found in the appendix, is therefore recommended.

II. The Actual Every-day Practice of American Steel Works in Determining the Physical Properties of Iron and Steel.

Introduction.

36. The following statements are based on replies received to a series of questions addressed to thirty-three steel companies, makers of over 75 per cent. of the open-hearth and Bessemer steel produced in the United States in 1899. The facts presented may therefore be accepted as fairly representing the commercial methods, for determining the physical properties of iron and steel, in present use in the United States.

In the following discussion, these commercial methods are compared wherever possible, with the conclusions, in reference to the testing of metals, adopted in 1894 by the French Commission on Methods of Testing Materials of Construction, appointed on November 9th, 1891, by a decree issued by the President of the French Republic; and with the resolutions of the International Conventions held in Munich in 1884 and 1885, in Dresden in 1886, in Berlin in 1890, and in Vienna in 1893.

The recommendations contained in the report of the Committee of the American Society of Mechanical Engineers, on "Standard Tests and Methods of Testing Materials" are not included in the discussion for the reason that the report was never endorsed or even thoroughly discussed by the Society.[1]

Testing Machines.

37. The thirty-three steel companies operate a total of seventy-three testing machines, varying in capacity from 130 pounds to 400,000 pounds. All these machines are of American manufacture, six makers of testing machines being represented.

Sixty-two of the seventy-three testing machines are operated by a screw, the other eleven by hydraulic pressure, with both of which methods, by proper handling, sudden shock-like action of the load may be prevented. This important feature of a machine is recommended by both the French Commission and the Conventions.

1 This report was presented to the Society in May, 1890, and is contained in their Transactions Vol. XI, pp. 604–653, Paper No. 380. The report is erroneously referred to by M. Baclé as the "Recommendations of the American Society of Mechanical Engineers," in an admirable comparative analysis of the Resolutions of the International Conventions, and the French Commission published by him in March, 1895.

In fifty-five of the seventy-three machines the poise is fed by hand, in the remaining eighteen machines by automatic arrangements. The Conventions state that for practical purposes no separate attachment making the machine self-acting is required.

The Conventions state that machines should be arranged in such a way that their adjustment can be verified with ease and certainty. This too is a feature of all American machines.

Methods of fastening the test specimen for tensile test.

38. The Conventions give explicit directions as to the modes of securing the specimens for tensile test. The arrangement must be such as to allow, as much as possible, uniform distribution of strain in the cross-section. There must be freedom and ease of movement, for adjustment of position at commencement of tension, and serrated wedges that cut into the test piece should never be used. They recommend spherical bearings for round specimens, and pin-hole and pin for flat bars or else milled heads clamped by proper wedges.

The French Commission do not forbid the use of serrated wedges.

The replies from the thirty-three American steel companies show a complete departure from the recommendations of the Conventions. Serrated V notched wedges are in general use for round specimens as rolled, and screw heads for turned specimens. Pin-hole and pins are not in use in America for the commercial testing of flat specimens. Crown faced, diagonally serrated wedges are used for flat specimens. The high face causes the specimen to align itself when put under strain, and also causes the serrations to imbed themselves firmly in the center of the head of the specimen. Slipping of the specimen is thereby prevented, nor are the edges of the specimen cut, thereby avoiding any danger of premature breaking from this cause. Ball-bearing grips were first adopted with the American type of testing machine. It was found that scale, rust, and other dirt constantly accumulated around the joints, thus preventing the freedom of motion necessary to make the device of any value. For this reason they have long since been generally abandoned, and the present forms of serrated wedges have been found to meet all practical requirements.

39. The thirty-three replies show a lack of uniformity in the rate, expressed in inches per minute, with which the load is applied in the determination of the yield point and tensile strength of the steel. Omitting the wire and tube testing machines, eighty-seven per cent. of the replies show a speed in use not exceeding three inches per minute.

Speed with which the load is applied in tensile tests.

The conventions refer to the investigations on this subject made by Fischer, Hartig, and Bauschinger, and while admitting that rate of testing undoubtedly influences tests, particularly when tracing diagrams of tensile tests, they conclude that as yet they have not sufficient ground for establishing any fixed velocity for testing iron, copper and bronze. The French Commission gives no positive rule with regard to the effect of the duration of the test, as it considers that the subject is not as yet sufficiently understood; it recommends, however, a further investigation of the subject. These remarks apply to scientific testing.

In commercial testing, however, the difficulty of obtaining very accurate calibration of rolled surfaces, and the fact that actual loads are seldom read nearer than 100 pounds, makes the results of the tensile tests practically the same within the variations of speed used in the commercial testing. Many experiments made by carefully following the commercial methods of testing, show that a difference in speed of from one to three inches per minute, makes no material difference in the tensile strength and elongation. The tensile strength is slightly increased, and the elongation slightly decreased by rapid testing.

40. In calipering tensile specimens thirty-two of the thirty-three steel companies measure to the nearest 0.001". With the tensile specimen of 0.500" diameter recommended in the specifications for steel castings, axles, forgings, and tires, an error in calipering of 0.001" makes a difference of 320 pounds per square inch, on a steel of a tensile strength of 80,000 pounds per square inch. With the tensile specimen recommended in the specifications for plate and structural steels, an error of 0.001" in calipering the thickness of the specimen, makes a difference of 241 pounds per square

Accuracy in Calipering Tensile Specimens.

inch, on a steel of a tensile strength of 60,000 pounds per square inch.

The Conventions in determining cross-sectional dimensions of specimens, recommend that readings shall be taken to 0.1 mm. (0.004″). The French Commission recommends a determination to within 0.05 mm. (0.002″) in the case of dimensions equal to or less than 10 mm. (0.394″), and it accepts an approximation to within 0.10 mm. (0.004″) when the length measured is greater than 10 mm. (0.394″).

The commercial methods used in American steel works for calipering tensile specimens, are therefore more accurate than the recommendations of either the Conventions or the Commission.

Accuracy in Reading Actual Loads.

41. The actual loads used as a basis for calculating the yield point and tensile strength per square inch are read to the nearest 100 pounds by fifty-two per cent. of the steel companies, to the nearest 50 pounds by nine per cent. and to the nearest 10 pounds by thirty-nine per cent. among which latter are included the manufacturers of wire and tubes. With a steel of a tensile strength of 80,000 pounds, a difference of 100 pounds in actual load is equivalent to 510 pounds per square inch, when using the standard turned specimen of 0.500″ diameter. With a plate steel of 60,000 pounds, when using the standard specimen of 8″ gauged length, a difference of 100 pounds in actual load is equivalent to 267 pounds per square inch.

The Conventions state that they will accept an error of 0.1 kilos per square mm. (142 pounds per square inch) when reading actual loads for calculating the yield point and tensile strength. The French Commission declares that for strains less than 5000 kilos (11023 pounds) a determination to within 25 kilos (55 pounds) is sufficient; when the strain exceeds 5000 kilos (11023 pounds) they allow 50 kilos (110 pounds); in other words to within 1/200 in the first case, and to within less than 1/100 of the total strain in the second case.

The American steel works practice of reading actual loads to within 100 pounds is virtually as accurate as that recommended by the Conventions or the French Commission, inasmuch as the actual loads read are usually over 10,000 pounds.

Accuracy in Reporting Tensile Strength and Yield Point.

42. The above limits of accuracy in commercial testing when calipering and reading loads, indicate that it is unnecessary to report the tensile strength and yield point closer than to the nearest 100 pounds per square inch. The replies to the question on this topic show that fifty-six per cent. of the steel companies follow this practice of reporting to the nearest 100 pounds per square inch. Six per cent. of them, however, report to the nearest 50 pounds per square inch, and no less than thirty-eight per cent. to the nearest 10 pounds per square inch.

Accuracy in Measuring Elongation.

43. The replies show that ninety-one per cent. of the steel companies measure the actual stretch of the specimen to the nearest 0.01″. With the standard specimen of 2″ gauged length, and with a steel of 20 % elongation, a difference of 0.01″ is equivalent to a difference of 0.50 %. With the standard specimen of 8″ gauged length, and a steel of 25 % elongation, a similar difference in actual stretch is equivalent to a difference of 0.125 % in the elongation.

The Conventions recommend a slightly higher accuracy than the above, in stating that the elongation at rupture should be measured to 0.10 %.

Accuracy in Reporting Elongation.

44. The American practice as quoted in preceding paragraph, shows that it is unnecessary to report the percentage of elongation closer than 0.10 %. The replies show that sixty-two per cent. of the steel companies follow this practice. Twenty-two per cent. of them, however, report to the nearest 0.01 %, nine per cent. to the nearest 0.25 %, and seven per cent. of the steel companies report elongation to the nearest 0.50 %.

Accuracy in Measuring Contraction of Area.

45. The replies to the circular inquiry show that the actual reduction at the point of fracture is measured to the nearest 0.01″ by forty-eight per cent. of the steel companies, and to the nearest 0.001″ by forty-five per cent. The remaining seven per cent. state that they measure reduction of area to the nearest 0.10″. With the standard turned specimen of 0.500″ diameter, a difference of 0.001″ in actual measurement is equivalent to 0.33 % in contraction of area with a steel

of 20 % contraction, and to 0.20 % when the steel has a contraction of area of 50 %.

The Conventions recommend that the reduction of cross-sectional area shall be measured to the nearest full per cent., a much wider allowance than that in use in America in commercial testing.

Accuracy in Reporting Contraction of Area.

46. As shown above, it is unnecessary when measuring contraction to the nearest 0.01" to report the percentage nearer than 0.20 %. The replies received show that seventy-seven per cent. of the steel companies adopt the practice of reporting contraction of area to the nearest 0.10 %. Nineteen per cent. of them to the nearest 0.01 %, and three per cent. to the nearest even per cent.

A review of paragraphs 37–46 inclusive, shows that the limits of accuracy in the commercial American methods for determining the physical properties of iron and steel, compare very favorably with the recommendations of International Conventions and the French Commission.

Methods for Yield Point and Elastic Limit.

47. The replies from the thirty-three steel companies show that the yield point is, in the majority of cases, determined only by the drop of the beam, or halt in the gauge of the testing machine. When any other method than the drop of the beam is required thirty-one per cent. of the companies report that dividers are used, and fifteen per cent. report that they use some of the various forms of special apparatus attached to the tensile specimen, by which an accurate elastic limit determination may be made.

Method for Bending Tests.

48. The Conventions recommend that bending tests be made by means of a slow working mechanical contrivance to act either by central pressure between two supports, or by lateral pressure on one of the ends of the specimen, the other being held by the clamp. The apparatus should be simple and capable of working rapidly. The part where the most strain takes place in the test specimen should be clearly visible. The bending should take place in a continuous way, and when it is done around a mandrel the diameter of such mandrel should be as small as possible.

At American steel works bending tests are much more often made by blows from a hammer than by steady pressure. With small bending test specimens sledges are used, and larger ones are bent under steam hammers. In some cases the test is started by a sledge and finished under the steam hammer. About twenty per cent. of the thirty-three steel companies report that their bending tests are made by hydraulic pressure. It will be recalled that the specifications given in the appendix state that bending tests may be made by pressure or by blows. The Conventions state that the duration of the bending test is of no importance.

49. The Conventions make the following statement under this heading :

Multiple or Piece Tests.

"There should be collected as much information as possible for the purpose of devising standard rules for multiple or piece tests (test of each piece in a lot).

"In deciding upon standard rules for impact testing machines and machines for tests of strength there should be kept in view the possibility of making multiple or piece tests.

"Not only axles should be thought of in this connection, but all construction material of steel and iron.

"The multiple or piece test, which consists in testing rapidly by a single shock, for example, each piece of a lot, in such a way as not to injure it, certainly offers more of a guaranty than that which consists in testing so many per cent. of the pieces of a lot. It has been adopted for a long time for springs, chains, pipes, steam pipes, boiler tubes, etc. It has given good results in Austria, where it has been used in a number of cases for axles. It must, however, be recognized that that method offers great difficulties for the buyer as well as for the seller, but those difficulties can be overcome by the study and adoption in practice of a well-suited mode of test. The only experience available so far in regard to multiple tests has been gathered at Witkowitz, with axles only, and has lately led to abandoning this method of test. It is desired, however, that more experience should be gathered."

The circular letter sent to the American steel companies asked them to state fully their experience with this method of testing. The replies received show conclusively that testing each piece of a lot, in such a way as not to injure it, is seldom made or called for in America. The American practice of testing every eye-bar, by applying a load similar to that which it would receive in ser-

vice, was abandoned as useless over eighteen years ago. Axles are not submitted to individual tests.

Certain special classes of steel springs are submitted to individual tests, by measuring length and height of spring before and after applying maximum working load. In some cases every boiler tube of a lot is subjected to hydrostatic pressure, and examination made of each tube for leaks, weakness, or other defects; but ordinarily only 3 out of every 100 are subjected to this test. Chains are sometimes tested by subjecting them to a working load. Water pipes, cylinders, and finished boilers are submitted to individual tests.

III. Methods in Use in American Steel Works for the Chemical Analysis of Steel.

Introduction.

50. A description of *all* methods in use in American steel works laboratories, by means of which satisfactory analytical determinations of the various constituents of steel are made, is far beyond the scope of this paper. In discussing methods for analysis the distinction must be kept in mind, as pointed out by von Juptner,"[1] between "works assays" and "precise analytical methods." Both classes of methods are included in those selected for description, and in some cases the method given fulfils the requirements of both classes. For this reason the time occupied in a determination, and the limit of accuracy, is given in each case, as well as the reactions on which the method is based.

Determination of Carbon.

51. Two methods for the determination of carbon in steel will be described:

(*a*) Gravimetric, by combustion in air in Shimer's crucible. Time, two hours and twenty minutes. Accuracy, 0.005 %.

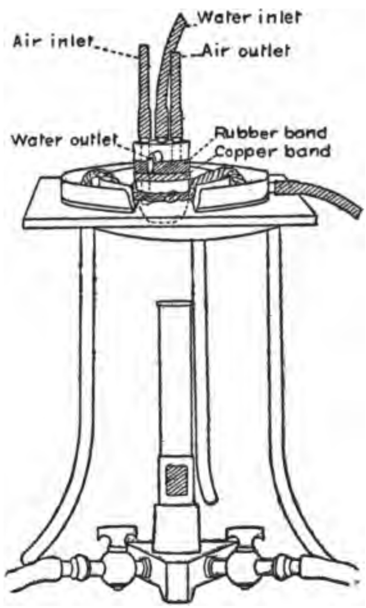
(*b*) Colorimetric, Eggertz method. Time, twelve minutes. Accuracy, from 0.01 % to 0.03 %, depending on the per cent. of carbon in the steel.

(*a*) *Shimer's Gravimetric Method.*—Mr. P. W. Shimer replaces the porcelain or platinum tube, ordinarily used in the determina-

[1] loc. cit.

tion of carbon by combustion in oxygen, by a platinum crucible provided with a water-cooled copper stopper, and a ring of sheet copper fitting closely around the extreme top of the crucible. This ring is flanged at the edges so as to carry off the flow of water from the water-cooled stopper. A band of pure black rubber just fitting the stopper, insures a tight joint. For further details of this excellent combustion apparatus, the reader is referred to Mr. Shimer's article[1] and to the accompanying illustration (Figure IV).

FIGURE IV.



The combustion is conducted in air, instead of oxygen. The combustion train consists of the following parts: 1. Two aspirator bottles, or other forms of apparatus, to force air through the train. 2. Geissler bulbs containing potassium hydroxide. 3. Guard bottle. 4. Combustion crucible, properly connected with reservoir of water, and waste for overflow. 5. Brass tube, 12″ long and 1/4″ in diameter, the middle 6″ of which is filled with copper oxide, kept hot by a Bunsen burner with wing top. Both ends of this brass tube are kept cool by wrapping with lamp-wick which dips into beakers of cold water. 6. A four-bulbed tube 6″ long filled with glass beads and kept cold by moist lamp-wick, or piece of cotton cloth as above. This bulb retains chlorine and hydrochloric acid. 7. Tube 6″ long filled with calcium chloride. 8. The Geissler bulbs with small calcium chloride tube attached. 9. A guard tube of calcium chloride.

The steel is dissolved in an acidulated solution of double chloride of copper and potassium. With a stirring machine to facilitate solution of the steel, Gooch crucibles and strong suction

[1] Journal of American Chemical Society, Vol. 21, July, 1899, pp. 557-568.

for filtering off and washing the carbon, convenient air-bath for drying, and two combustion outfits, eighteen determinations have been made daily by one man working ten hours, and a single determination in two hours and twenty minutes from the time the drillings of steel were handed to the operator. This method for the gravimetric determination of carbon is accurate within 0.005%.

(*b*). *Eggertz Colorimetric Method.*—This method, proposed by Eggertz in 1862,[1] depends on the depth of color imparted by the combined carbon to a nitric acid solution of the steel. It is undoubtedly the most generally used, and, also the most frequently abused method in use in steel works laboratories. If the following general precautions are carried out the method will give satisfactory results, in both high and low carbon steels.

(*aa*) The standard steel, with accurately known carbon content, and the samples to be tested should be of similar chemical composition especially in carbon, and should have received the same mechanical treatment.

(*bb*) Hardened steels should be thoroughly annealed, preferably in lime; and if over 0.60% in carbon may advantageously be hardened in water prior to the annealing. The standard steel used in this case should have been annealed before drillings or turnings were taken.

(*cc*) Equal weights of the standard steel and of the samples to be tested, should be taken, and the same quantity of nitric acid (sp. gr. 1.2) added to standard and to samples tested. During solution, the test tubes, containing the drillings of the standard steel, and of the samples to be tested, should remain in cold water, and be subsequently heated, under entirely similar conditions; the comparisons in the graduated tubes should also be made promptly after the samples are completely dissolved, and the solutions cooled.

(*dd*) The amount of nitric acid used in dissolving the steel should vary with the carbon present. The following table, showing the amount of acid used, the per cent. of carbon present in the standard steel used for steels of varying carbon, and the method of calculating the per cent. of carbon in the sample steel, is the result of a long experience with the Eggertz method.

[1] Jern-Kontorets Annalen, 1862, p. 54; 1874, p. 176; 1881, p. 301; Chemical News, VII, p. 254; XLIV, p. 173.

Range in per cent. carbon.	No. cc. acid added.	Weight taken. Grammes.	Per cent. carbon in standard steel.	Standard diluted in comparison tube to	To calculate per cent. carbon in steel tested, the reading of graduated tube should be		
1.20–0.80	7	0.2	1.04	20.8 cc.	Divided	by	20
0.79–0.60	6	0.2	0.68	13.6 "	"	"	20
0.59–0.50	5	0.2	0.58	11.6 "	"	"	20
0.49–0.50	5	0.2	0.49	9.8 "	"	"	20
0.39–0.23	4	0.2	0.34	6.8 "	"	"	20
0.22–0.14	4	0.2	0.201	6.7 "	Multiplied	by	0.03
0.13–0.10	3	0.2	0.114	5.7 "	"	"	0.02
0.09–0.06	3	0.2	0.082	4.1 "	"	"	0.02

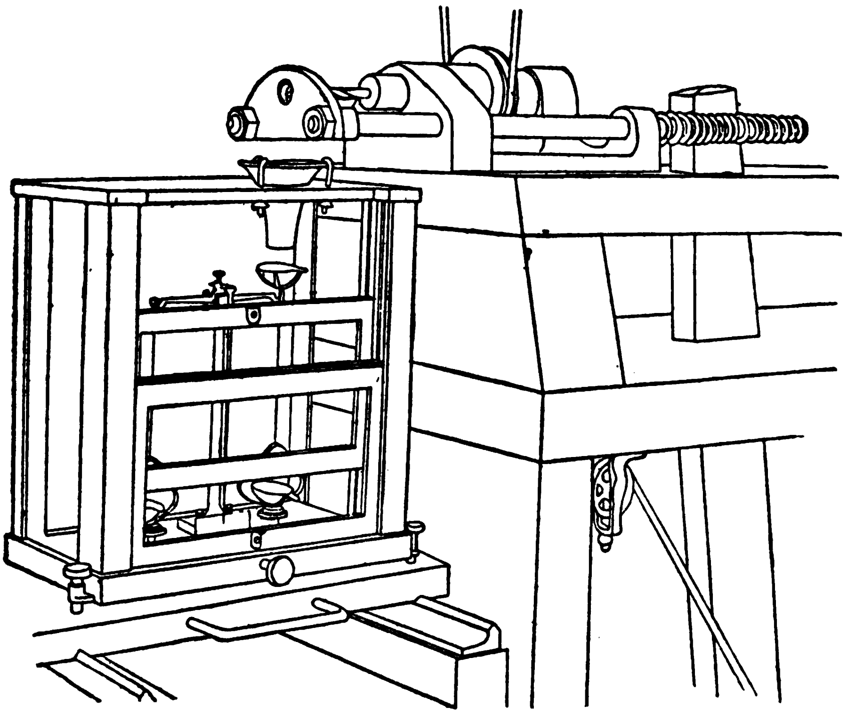
Special apparatus has been devised which greatly facilitates the application of the Eggertz method to the rapid determination of carbon in consecutive blows of Bessemer steel. The sample of each blow should be sent to the laboratory in the form of a flat bar about 7/8″ by 3/8″ by about 8″ long. These bars may be most conveniently obtained by passing the small test ingot through a set of small rolls. At some mills the test ingot is hammered into a bar. In either case the bar should be allowed to cool slowly on refractory bricks. It should not come in contact with a cold metal surface during cooling.

The bar may be very conveniently and rapidly drilled and weighed, in one operation, by use of the drill press and balance shown in Figure V; and the operator by means of the apparatus shown in Figure VI, which is located near the drill and balance, can add gradually any quantity of nitric acid up to 10 cc. to the drillings of one sample, while he is drilling, weighing, and transferring to the test-tube, the next sample to be analyzed.

The solution of the drillings may be materially hastened by heating in a calcium chloride bath, kept at 110° C. by high pressure steam, instead of in boiling water; and when dissolved the solution may be rapidly cooled by transferring the test-tubes to an unglazed earthenware vessel filled with water, which is kept cold by evaporation from the exterior surface of the vessel. The mixing of the solution in the graduated comparison tube is greatly facilitated by having the upper ends of the tubes bent to

an angle of about 110°. The colors are best compared in a so-called "camera," or box blackened inside; and when determinations are required both night and day, and the operators

FIGURE V.



change shifts each week, it has been found advantageous to place the camera in a small dark room, and illuminate the ground glass of the camera with an incandescent light, the yellow rays of which are neutralized by a sheet of blue tissue paper.

By means of these special forms of apparatus one operator, assisted by a boy to bring the test bars to the laboratory, and carry the reports back to the mill, has regularly reported the carbon in one-hundred samples of steel every twelve hours, the steel varying from 0.08 % to 1.00 % carbon, thus requiring the use of many different standard steels. A single determination is easily

made, with the above forms of special apparatus, in twelve minutes. By strict attention to all the precautions cited, the Eggertz method is accurate to within 0.01 % in steel below 0.40 % carbon, within 0.02 % in steel 0.40 %–0.80 % carbon, and to within 0.03 % in steel containing from 0.80 % to 1.20 % carbon.

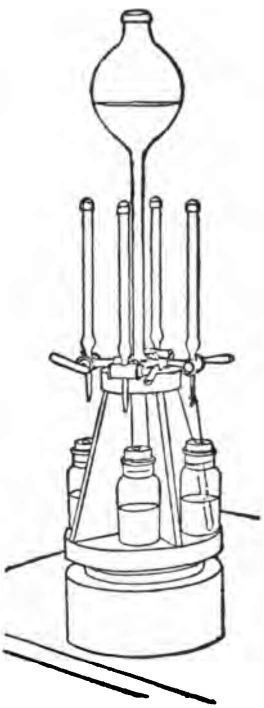
Determination of Manganese.

52. Of the many methods in use for the determination of manganese in steel, two will be briefly noticed.

(*a*) Williams' volumetric method. Time, thirty minutes. Accuracy, 0.01 %.

(*b*) Deshay's volumetric method. Time, twelve minutes. Accuracy, 0.02 %.

FIGURE VI.



(*a*) *Williams' Volumetric Method.*—This method is based upon the complete oxidation of manganese to manganese dioxide, by the addition of potassium chlorate to a concentrated nitric acid solution of the steel; the solution of this separated dioxide in a measured excess of ferrous sulphate, and the determination of the amount of ferrous sulphate, not oxidized by the precipitated manganese dioxide, by titration with potassium permanganate solution.

Three grammes is a convenient amount of drillings for analysis. The precautions necessary in the solution of the steel, and in the precipitation of the dioxide, have been frequently published. The filtration of the dioxide, which is the chief source of delay, may be rapidly effected by using a funnel tube 10 inches tall, 1 inch in diameter, and of a capacity of 100 cc.; and placing a circular piece of platinum gauze in the bottom of tube on which a loosely packed asbestos filter is formed; the filtration is hastened by use of suction. The beaker, funnel, and precipitate are washed with cold water, and the entire contents of the funnel transferred back into the beaker, and an accurately measured excess of fer-

rous sulphate rapidly added from the apparatus shown in Figure VII. The solution of the dioxide is facilitated by the use of a glass rod, flattened on the end; when solution is effected, the unoxidized ferrous sulphate is titrated with a standardized permanganate solution. By adopting a constant volume of ferrous sulphate, and by use of tables, the calculations necessary to determine the percentage of manganese are rapidly made. The method is accurate to within 0.01 %. The method readily adapts itself to the determination of manganese in ten or twenty steels at a time. A single determination occupies thirty minutes.

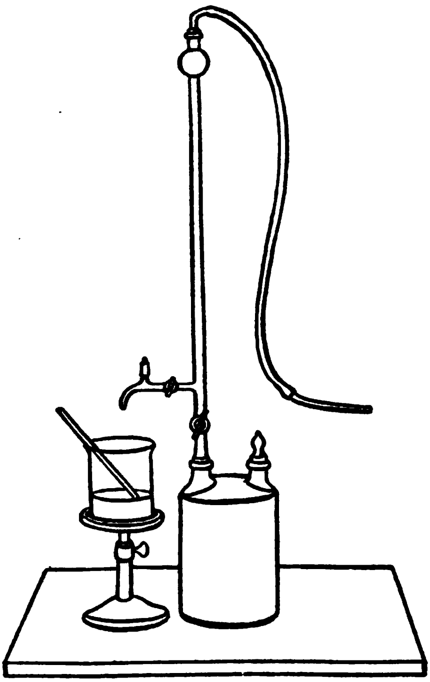
(*b*) *Deshay's Method.*—This method is based on the oxidation of the manganese to permanganic acid, by adding lead dioxide to a nitric acid solution of the steel; the separation of the lead dioxide, and the titration of the permanganic acid in the filtrate, by means of sodium arsenite.

By a careful attention to details the complete oxidation of all the manganese may be relied on, and by using a centrifugal machine to separate the lead dioxide, instead of the tedious method of filtering such a fine powder through asbestos, a method has been developed by which the manganese has been regularly reported on consecutive blows of Bessemer steel before the ingots were rolled, a feature of great practical value when making steel of a guaranteed manganese as well as carbon. This method has also been found of great practical value, when making special open-hearth steels, as the percentage of residual manganese in the bath is a valuable guide in the recarburization of the metal.

The special apparatus by means of which these results may be accomplished, consists of the drill and balance for rapid weighing of the sample shown in Figure V; the apparatus illustrated in Figure VI for accurately and rapidly adding the nitric acid used to dissolve the sample; and a calcium chloride bath kept at a temperature of 140°–150° C. for the rapid solution of the sample, and to insure the complete oxidation of the manganese to permanganic acid when the lead dioxide is added. Also a centrifugal machine, which completely separates the lead dioxide in five minutes if revolved 1200 revolutions per minute, and finally, for the

sodium arsenite solution, an accurately graduated burette and supply bottle of the form shown in Figure VII. The end reaction in titration is rendered more distinct if the beaker rests on a

FIGURE VII.



ground glass plate, forming the top of a small box containing an incandescent lamp.[1]

The determination is uniformly accurate to within 0.02% in steels below 1.5% manganese. By means of the special apparatus above referred to, a single determination may be made in twelve minutes including even the drilling of the piece of steel submitted for analysis.

[1] The rapidity of the process, made possible by the use of the centrifugal machine, prevents any decomposition of the permanganic acid, a recognized source of error in this method when the lead dioxide is removed by the slow process of filtration.

Determination of Silicon.

53. For the determination of silicon in steel, Drown's method has been found very satisfactory. It is accurate to within 0.005%. Time occupied, thirty minutes.

The method depends upon the oxidation of the silicon in the steel to silica, and its complete dehydration and separation, by the evaporation, to copious sulphuric anhydride (SO_3) fumes, of a nitric acid solution of the steel to which sulphuric acid has been added.

The dehydration may be conveniently effected, by adding 75 cc. of a mixture of one part concentrated nitric acid, one part concentrated sulphuric acid, and three parts of water to 4.7020 grammes of drillings contained in a covered 6″ best quality porcelain dish, and boiling rapidly over a large Bunsen burner to partial dryness, or until copious fumes of sulphuric anhydride (SO_3) appear. The silica filters more quickly if the cooled mass is first well moistened with concentrated hydrochloric acid (30 cc.) boiled a moment, and then diluted with hot water and heated until solution is clear. Further details are unnecessary. With the factor weight of drillings taken for analysis, the weight of the ignited precipitate, multiplied by ten, gives the percentage of silicon in the steel.

Determination of Phosphorus.

54. Probably the two following methods, with, of course, variations in detail, are the ones most generally used in American steel works laboratories, for the determination of phosphorus in steel.

(*a*). The Drown-Emmerton method. Time, thirty minutes. Accuracy, 0.002%.

(*b*). The Handy-Manby method. Time, ten minutes. Accuracy, 0.003%.

(*a*). *The Drown-Emmerton Method.*—This method depends on the conversion of all the phosphorus, in a nitric acid solution of the steel, into orthophosphoric acid by means of potassium permanganate; the reduction of the manganese dioxide formed, by a small amount of sugar; and the precipitation of the phosphorus by ammonium molybdate. The yellow precipitate may be weighed as such; or preferably dissolved in ammonium hydroxide, the solution acidulated with sulphuric acid, and the molybdic oxide, forming a known proportion of the phosphomolybdate precipi-

tate, reduced to molybdous oxide by passing the solution through a column of amalgamated zinc, and then oxidizing by a standard solution of potassium permanganate. Attention has frequently been called to the many little details of the process which long experience has shown to be necessary, to insure accuracy. It is notably a method in which success is only attained by experience.

The solution of the steel, and precipitation of the phosphorus, may be conveniently effected in an Erlenmeyer flask. The phosphorus is completely precipitated by agitation for five minutes. Suction is used in filtration; special forms of reductors and permanganate burettes have been devised which contribute materially to the rapidity of the process, and its adaptability to the determination of phosphorus in ten or twenty steels at a time. The method is accurate to within 0.002 % in steels of 0.10% phosphorus or below. A single determination may be readily finished in thirty minutes when using 4 grammes of drillings for the analysis.

(*b.*) *The Handy-Manby Method.*—Two grammes are usually taken for analysis, when this method is used, and the solution and oxidation, as well as the removal of the manganese dioxide, is effected as with Drown's method. The filtered yellow precipitate is dissolved in the same Erlenmeyer flask in which solution of steel was made, by the addition of an excess of standardized sodium hydroxide solution. The amount of free alkali remaining, is determined by titration with a standard nitric acid solution, phenol-phthaline being used as an indicator.

As stated above, a determination of phosphorus, accurate to 0.003 %, may be made by this method in ten minutes; the method is therefore particularly applicable where information is desired as to the progress of dephosphorization during the manufacture of basic open-hearth steel.

Determination of Arsenic.

55. In routine work this determination is seldom required, as it is now generally recognized that arsenic exercises no deleterious influence in the amounts present in commercial steels; and furthermore that it should not be classed with phosphorus, in its effect on steel. (See paragraph 65, page 52.)

The best method for its determination, consists in brief in obtaining a solution of the steel in nitric, and then in sulphuric

acid, and removal of all excess of the latter acid; distillation of the arsenic as chloride, by means of ferrous sulphate and hydrochloric acid; precipitation of the arsenic in the distillate, by sulphuretted hydrogen; and final weighing as arsenious sulphide, with all the usual precautions. Ten grammes of drillings are usually taken for analysis, and the method occupies twelve hours. It is accurate to within 0.003 %.

Determination of Sulphur.

56. Two methods for the determination of sulphur in steel will be briefly noticed.

(*a*) Gravimetric method. Time, six hours. Accuracy, 0.002 %.

(*b*) Volumetric method. Time, thirty minutes. Accuracy, dependent upon the amount of sulphur and carbon present, but may be given as 0.005 % under the best conditions.

(*a*) *Gravimetric Method.*—The success of this method depends in part, on the complete oxidation of the sulphur during solution of the steel drillings in aqua regia, and in part, on the proper neutralization of the solution before the addition of barium chloride, so as to insure the complete precipitation of the barium sulphate, free from imprisoned barium chloride. Lack of space prevents a description of the method, for, to be of real value, it must enter into the details of every step in the analytical process. If 5.5024 grammes of drillings are taken, the weight of the precipitate, divided by 4 and multiplied by 10, gives the percentage of sulphur. A determination may be completed in six hours. In routine work, on a large number of samples, it is customary to start them in the afternoon, and filter and weigh the precipitates the following morning.

(*b*) *Volumetric Method.*—All of the methods for the determination of sulphur in steel, that depend on the evolution of sulphuretted hydrogen, are open to the criticism that a portion of the sulphur escapes in the gases, probably as mercaptans. The error due to this cause is not over 0.005 %, in a steel of 0.040 % sulphur or below, but is much greater than this in higher sulphur steels; moreover, it is not a constant error, as it varies with the carbon as well as the sulphur in the steel.

The method in which the sulphuretted hydrogen is passed into

cadmium chloride solution is perhaps the one in most general use. The precipitated cadmium sulphide, suspended in a large volume of water, is dissolved in hydrochloric acid, starch solution added, and the standard iodine solution rapidly added from a burette, to oxidize the liberated sulphuretted hydrogen. The usual amount taken for analysis is 5 grammes; 1 cc. of the iodine solution is equivalent to 0.01 % sulphur. Many convenient forms of generating apparatus have been devised by chemists using this method. The time occupied is thirty minutes.

Determination of Nickel.

57. The best method for the determination of nickel and cobalt in steel, consists in dissolving the drillings in hydrochloric acid, with a little nitric acid, and separating the nickel and cobalt chlorides from the ferric chloride by means of ether in which reagent the ferric chloride is soluble. After separation of these two solutions by gravity, and removal of the small amount of ether associated with the nickel and cobalt by boiling, the small amount of iron still present is removed by two precipitations with excess of ammonia, and the nickel and cobalt in the filtrate (together with any copper present) is precipitated electrolytically in presence of an excess of ammonium chloride. The copper is separately determined on a larger weight of sample, and its percentage deducted from that of the nickel and cobalt.

When employing a direct current used for incandescent illumination, the process is greatly facilitated by the use of a resistance frame, made of "Tico" resistance wire, by which means the number of amperes used, may be regulated to suit the number of electrolytical determinations to be made. One gram of sample is taken for the determination of the nickel and cobalt. The method is accurate to within 0.02 %, and a single determination requires but two hours.

Determination of Chromium.

58. The best method for the determination of chromium in steel consists in the oxidation of the chromium to chromic acid, by the addition of an excess of potassium permanganate, to a sulphuric acid solution of the steel; the removal of the manganese dioxide by filtration; the reduction of the chromic acid by an excess of a standard solution of ferrous sulphate; and a determination of the amount of ferrous sulphate

unoxidized, by a standard solution of potassium permanganate. From 1 to 3 grams of drillings are taken for analysis. The method occupies two hours, and is accurate to within 0.02%.

59. For an accurate determination of copper in steel 10 grammes should be taken. The copper is precipitated as cuprous sulphide, by sodium thiosulphate, filtered, ignited to cupric oxide, dissolved in nitric and sulphuric acids, filtered, and the copper deposited on a small platinum cylinder by a current of 3 amperes. The method requires six hours. It is accurate to within 0.002%.

Determination of Copper.

60. The usual method for the determination of tungsten in steel, consists in the separation of the tungsten as oxide by evaporation of a nitric acid solution of the steel (3 to 5 grammes); dissolving the iron in hydrochloric acid, filtering and dissolving the impure tungstic oxide in concentrated ammonium hydroxide; filtering and evaporating in a platinum dish, and igniting and weighing the tungstic oxide. In steels containing 5.0% to 9.0% tungsten, the method is accurate to within 0.04%. The time required is twelve hours.

Determination of Tungsten.

61. Eggertz method is the best short practical method for the determination of slag and oxides in steel. It consists in dissolving the drillings in a cold aqueous solution of recrystallized iodine; frequent agitation is necessary. In filtering the residue, it must be thoroughly washed, finally with hot water, until iodine and iron salts are removed. The filter-paper is then spread out on a clock glass, and the residue washed into a platinum dish with a fine stream of potassium hydroxide using 50 cc. in all. The solution is next gently boiled for ten minutes, diluted and filtered, and the residue carefully and thoroughly washed with water, hydrochloric acid, and finally hot water. After careful ignition the residue is weighed and reported as slag and oxides.

Determination of Slag and Oxides.

The method occupies six hours. In soft steels containing 0.200% of slag and oxides, duplicates always agree to within 0.02%. The method gives results which are fairly comparative in mild steels of *uniform* carbon, but it is entirely inapplicable for steels of high carbon, as a carbide of iron insoluble in the iodine, is finally ig-

nited into oxide of iron, and reported *as if it existed as oxide* in the steel.

The only method by which the *total* oxygen present in steel can be accurately determined is that proposed by Ledebur, consisting of the ignition of the sample in a current of chlorine, followed by ignition in a current of hydrogen.[1]

IV. Critical Review of Foreign Specifications for Steel Rails.

Introduction. 62. The following official statistics show the marked increase in the tonnage of steel rails exported from America in recent years.

1894	12,229	gross tons
1895	8,807	" "
1896	72,503	" "
1897	142,808	" "
1898	291,038	" "
1899	171,272	" "

The specifications for steel rails issued by foreign railroads and engineers, are, therefore, a matter of practical interest in America. It was hence thought advisable, having finished the discussion of American specifications and methods of testing for the various kinds of steel, to add a few words in criticism of foreign rail specifications, from an American standpoint. The remarks have a practical interest to the foreign purchaser of rails, as they will point out certain features in their specifications unnecessary in the present state of the art, which are looked upon as hardships by the American manufacturer because they increase the cost of manufacture, and hence the price of the rails, without, in any manner, improving the quality of the product.

63. In a review of forty-one foreign rail specifications, eight

[1] Stahl und Eisen, Vol. II (May, 1882), p. 193, etc.; Dingler's Polytech. Jour., 245 (Aug., 1882), p. 293; abstracted in Jour. Soc. Chem. Ind., Vol. I (1882), p. 366-7; Jour. Iron and Steel Inst., No. 1 (1882), p. 383; Jour. Chem. Soc., Vol. XLIV (1883), p. 121-2; Trans. Amer. Inst. Min. Eng., Vol. XXIV (1894), p. 791-3; Leitfaden für Eisenhütten Laboratorien, 1896, by A. Ledebur.

Stahl und Eisen, Vol. XIII (1893), p. 245, etc., P. Gladky; Stahl und Eisen, Vol. XIII (1893), p. 293, etc., A. Ledebur; Stahl und Eisen, Vol. XIII (1893), p. 1094-6, P. Gladky; Stahl und Eisen, Vol. XV (1895), p. 580-1, A. Ledebur.

were found which limit the manufacturer to the use of "the best English or Spanish hematite pig iron and charcoal spiegeleisen." This requirement, of course, cannot be complied with in American mills, nor in the present state of the art, does it seem a necessary stipulation in any case, particularly as, if strictly interpreted, it seriously limits competition.

The Processes of Manufacture Specified.

64. (*a*) *Carbon.*—In 63 % of the forty-one foreign specifications reviewed, limits in carbon are specified, and in the majority of these cases a range of carbon of from 0.10 to 0.15 % is given. This is in general accord with American practice, except that the American specification increases the carbon gradually with the increased weight of section, specifying in each case a range of 0.10 %.

The Chemical Properties Specified.

The actual percentages of carbon given in foreign specifications will not be discussed, further than to say, that with the rapid rail rolling at present in vogue in America, resulting in higher finishing temperatures than foreign mills, the carbon in the steel may be safely increased by the foreign engineer over that called for in the specification, when the rails are furnished from American mills. He will thereby obtain a better wearing rail without, in any way, diminishing its safety.

Some American rail mills have recently been successful in experiments looking towards the finishing of rails, at a lower temperature than at present in vogue, without diminishing the present output. This improvement will therefore doubtless be adopted in the near future, in which event it will be unnecessary for foreign engineers to increase the carbon of their specifications, when obtaining rails from American mills.

The proper *structure*, to insure safety and wearing qualities, is what is desired in rails, and as the percentages of carbon and other hardening elements which will give this structure, vary with the finishing temperatures, the chemistry must be changed to suit the varying conditions of manufacture. In short an international standard composition for rails is utterly impracticable, and it is useless for any country or engineer, to assert that their composition is the best and should be therefore adopted in all countries.[1]

[1] See C. P. Sandberg's paper "The danger of using too hard steel rails." Journal Iron and Steel Institute, No. 2, 1898, pp. 76–110; especially p. 106.

(*b*) *Phosphorus and Sulphur.*—Thirty-two per cent. of the foreign specifications reviewed, call for a phosphorus and sulphur of 0.06 % or below. Rails meeting these requirements will be furnished in America, at, of course, a considerably higher price than charged for rails of 0.10 % phosphorus which latter forms by far the largest proportion of the product of American rail mills. Many thousands of tons of American rails of 0.10 % phosphorus have given satisfactory service under severe conditions. The increased cost of 0.06 % or 0.08 % phosphorus rails, over that of rails containing 0.10 % phosphorus, does not, in the opinion of many competent judges in America, obtain a correspondingly safer or better rail from American mills.

(*c*). *Silicon and Manganese.*—About one-half of the foreign rail specifications examined, mention limits in silicon and manganese. The silicon specified varies from 0.06 % to 0.25 %. The manganese varies between the wide limits of 0.40 % and 1.20 %. American mills would not be inclined to furnish rails on a specification limiting the manganse to 0.40 %, the requirement mentioned in one specification examined. The American standard specifications for rails states that silicon shall not exceed 0.20 %; and gives a range of 0.30 % in manganese, the limits varying with the increased section between 0.70 % to 1.10 %.

In general it may be stated that the strict adherence by a foreign engineer to a specified complete chemical composition, independent of the varying conditions of manufacture, and the rejection of large lots of rails *solely* because the sample, assumed to represent the lot, exceeds in some respects the specified chemistry, compels his client to pay much more than is necessary to obtain a first-class rail to-day from American mills.

Sample for Analysis.

65. Some foreign specifications require that every heat of rail steel shall be analyzed for phosphorus and arsenic, and stipulate that if the phosphorus and arsenic exceed 0.06 % the heat is not to be used. It has been conclusively proved that arsenic should not be classed with phosphorus in its effect on the physical qualities of the steel.[1] Furthermore, as there is no

[1] F. W. Harbord and A. E. Tucker. Journal Iron and Steel Institute, No. 1, 1888, pp. 183-196, and No. 1, 1895, pp. 131-132 and 127-128.
J. E. Stead. Journal Iron and Steel Institute, No. 1, 1895, pp. 77-140.

rapid method by which both phosphorus and *all* of the arsenic can be determined, the ingots of each blow could not be held for analysis, but must be rolled into rails and subsequently rejected if the analysis shows a phosphorus and arsenic of over 0.06 %. This burden, with the unnecessarily frequent analysis demanded, will not be assumed by the American manufacturer without substantial remuneration, and will more often result in a refusal to bid unless this requirement of the specification be withdrawn.

Another very arbitrary clause in certain foreign specifications, states that each 500 tons of finished rails will be accepted or rejected on the analysis of a piece of *one* rail, selected by the engineer, said analysis to be made, at the contractor's expense, by an independent chemist selected by the engineer. In American mills the rails pass over several cooling beds, and are drilled on many sets of presses. Without great additional labor it is therefore impossible, to land the finished rails of consecutive heat numbers in 500 ton piles in the yard, to await the complete analysis of the independent and probably distant chemist. In the light of all that has been published, and candidly admitted by the manufacturer, as to the unavoidable variations in composition even of the different parts of a section of rail, to say nothing of the variation of different rails of a blow, how can an engineer conscientiously accept or reject 500 tons of rails from the analysis of a single rail?

The Physical Properties Specified.

66. (*d*) *Tensile Strength and Elongation.*—With a specified chemical composition, a drop test, and, in most cases, a dead weight test also, tensile strength and elongation is an unnecessary requirement. In fact when carbon, and other hardening elements are specified and strictly adhered to, the tensile strength and elongation should not also be made the subject of specification. Fifty-four per cent. of the forty-one specifications reviewed, call for determination of tensile strength and elongation, and in five of these twenty-two, contraction of area is also specified; in three a bending test is also required. Of these twenty-two specifications, fourteen, or 34 % of the total number examined, specify both chemical composition and tensile requirements. Tensile specimens represent, at best, only a small part of the cross section of the

rail. If taken from the center of the head, the results are affected by the segregation of the hardening elements, and do not represent the portion of the metal subjected to greatest strains in service; if taken from this portion, namely the exterior surface, the results are apt to be affected by the presence of a few partly welded blow holes. In neither case, therefore, can the tensile specimen be considered as fully representing the rail from which it was cut, much less any lot of rails from which the sample was selected.

(*e*) *Drop Tests Specified.*—All the foreign specifications reviewed, very properly contain a drop test; some of the drop tests specified, however, are open to considerable criticism. Where chemical composition is specified, and faithfully followed, the drop test should not include a certain maximum deflection, but should simply specify that the piece of rail shall not break under a single blow on the head, the tup falling from a height increasing with the weight of the rail section. Where the engineer prefers to include a certain maximum deflection in the drop test, besides specifying that the piece of tested rail shall not fracture, the percentage of carbon should be omitted from the chemical requirements. Either method will insure a safe hard rail, but a specified range of 0.10 % in carbon is perhaps a better and more prompt means of securing and maintaining uniformity in the product.

(*f*) *Dead Weight Tests Specified.*—This transverse test under static load should include a determination of the yield point, and by means of still heavier loads beyond the yield point, the determination of greatest permanent deflection. The test may be looked upon as unnecessary when the chemical composition is fully specified and the ability of the finished rails to withstand shock determined by a drop test. However, the requirements of the dead weight tests contained in foreign specifications are met without difficulty by American mills. Seventy per cent. of the forty-one specifications examined specify a dead weight test, but in quite a number only a weight is used which shall give no permanent set. The test is, therefore, frequently regarded in American mills as at least unnecessary, for when the loads specified are within the elastic limit of the steel, the deflections are merely factors of the section of the rail.

67. Some foreign specifications require, even after the templets have been approved by the engineer, resident abroad, that a section of the rail 12" long must be submitted to the foreign engineer, and approved in writing before the general rolling can proceed. This is a needless delay, as confidence can be safely placed in the skill and integrity of American manufacturers.

Finish.

In a number of foreign specifications the permissible variations in height of sections are too rigidly drawn to allow for the unavoidable wear of the rolls. Smoothness of track is in no wise jeopardized by an allowance of 1/64" under and 1/32" over the specified height; they are the variations permitted by the best American railroads. A number of foreign specifications allow a less variation in length of rail than 1/4", which is the uniform practice of American railroads.

Most foreign specifications allow a variation in weight of 1 %, for individual rails. This can be easily reduced to 0.50 % for the entire order, but the rails should be paid for on actual, and not estimated weights.

68. In this respect foreign specifications conform to the American practice in requiring, as a general rule, that the name of the maker, the month, and year of manufacture be legibly rolled in relief on the web of each rail; and that each rail shall also be stamped with the number of the blow from which it is made.

Branding.

69. American mills are noted for their willingness to afford the inspector every facility to enable him to satisfy himself that the rails are being furnished in accordance with the specifications. In return they have a right to expect from a foreign purchaser, inspection which shall not delay manufacturing operations. This is by no means always realized, and as it is a frequent cause of expensive and annoying delays, it is a proper subject of comment.

Inspection.

The inspectors sent to American mills are frequently unfamiliar with rail inspection, and are, therefore, too strict in their inspection, and too slow in their decisions. Again when the specifications require all four sides of every rail to be examined for flaws, all holes gauged, each rail tested for length and squared

on each end, and stamped in four places by the inspector's mark, and also require him to be present at the testing, to weigh 1 % of the rails, and to watch the loading of the rails to see that only those bearing his stamp are loaded, it is manifestly unfair to the manufacturer to send but one inspector to the mill and expect the manufacturer to conform his product to the number of rails that one inspector can pass upon, in nine or ten hours of the twenty-four. Lack of inspectors frequently necessitates a change of rolls at the mills, and has delayed the departure of vessels on which the rails were being loaded. Assuredly enough inspectors should be furnished to inspect the entire product of the mill each day.

Some foreign specifications require that all rejected rails shall be piled up and kept until the completion of the contract, so that, at any time, the inspector may check them with the numbers entered in the book; and that no rejected rail shall be sold or broken until the completion of the contract. This is manifestly unfair to the manufacturer, as on a large contract, not continuously rolled, a considerable tonnage of second quality rails might be tied up, which might otherwise be sold. Some foreign specifications state that the final acceptance of the rails and splice bars, shall be at the port of delivery. This is unreasonable; final acceptance should be based on tests and inspection made at the place of manufacture.

The writer is confident that foreign purchasers have no desire to knowingly include in their specifications, requirements, which, while securing no more efficient product, operate to limit competition, and increase the cost of inspection and the price of product. This thought prompted the foregoing criticism of foreign rail specifications, which, it is hoped, will result to the mutual advantage of the foreign customer, and the American mills.

APPENDIX.

Specifications for Steel and Wrought Iron

ADOPTED BY

COMMITTEE NO. 1

OF THE

American Section of International Association for Testing Materials.

APRIL, 1900.

CONTENTS OF APPENDIX.

STEEL CASTINGS.

PROCESS OF MANUFACTURE.

1. Steel for castings may be made by the open-hearth, crucible or Bessemer process. Castings to be annealed or unannealed as specified.

CHEMICAL PROPERTIES.

Ordinary Castings.

2. Ordinary castings, those in which no physical requirements are specified, shall not contain over 0.40 per cent. of carbon, nor over 0.08 per cent. of phosphorus.

Tested Castings.

3. Castings which are subjected to physical test shall not contain over 0.05 per cent. of phosphorus, nor over 0.05 per cent. of sulphur.

PHYSICAL PROPERTIES.

Tensile Tests.

4. Tested castings shall be of three classes: "HARD," "MEDIUM," and "SOFT." The minimum physical qualities required in each class shall be as follows:

	Hard castings.	Medium castings.	Soft castings.
Tensile strength, pounds per square inch	85,000	70,000	60,000
Yield point, pounds per square inch....	38,250	31,500	27,000
Elongation, per cent. in two inches	15	18	22
Contraction of area, per cent...........	20	25	30

Drop Test.

5. A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile and free from injurious defects, and suitable for the purposes intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

Percussive Test.

6. Large castings are to be suspended and hammered all over. No cracks, flaws, defects, nor weakness shall appear after such treatment.

7. A specimen one inch by one-half inch (1" x 1/2") shall bend

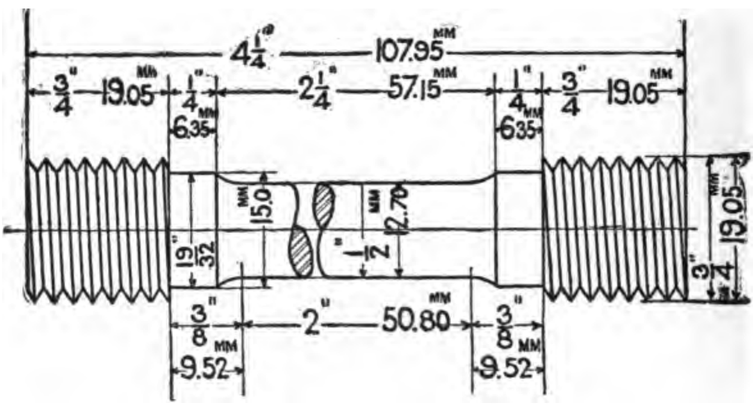
Bending Test.

cold around a diameter of one inch (1″) without fracture on outside of bent portion, through an angle of 120° for "SOFT" castings, and of 90° for "MEDIUM" castings.

TEST PIECES AND METHODS OF TESTING.

Test Specimen for Tensile Test.

8. The standard turned test specimen, one-half inch (1/2″) diameter and two inch (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 4. It is shown in the following sketch:



Number and Location of Tensile Specimens.

9. The number of standard test specimens shall depend upon the character and importance of the castings. A test piece shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings, before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

Test Specimen for Bending.

10. One specimen for bending test one inch by one-half inch (1″ x 1/2″) shall be cut cold from the coupon or sink-head of the casting or castings as specified in paragraph No. 9. The bending test may be made by pressure, or by blows.

Yield Point.

11. The yield point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Sample for Chemical Analysis.

12. Turnings from the tensile specimen, drillings from the bending specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in phosphorus and sulphur specified in paragraphs Nos. 2 and 3.

FINISH.

13. Castings shall be true to pattern, free from blemishes, flaws or shrinkage cracks. Bearing surfaces shall be solid, and no porosity shall be allowed in positions where the resistance and value of the casting for the purpose intended, will be seriously affected thereby.

INSPECTION.

14. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STEEL AXLES.

PROCESS OF MANUFACTURE.

1. Steel for axles shall be made by the open-hearth process.

CHEMICAL PROPERTIES.

2. There will be three classes of steel axles which shall conform to the following limits in chemical composition.

	Car, engine truck and tender truck axles. Per cent.	Driving wheel axles. (Carbon steel.) Per cent.	Driving wheel axles. (Nickel steel.) Per cent.
Phosphorus shall not exceed.....	0.06	0.06	0.04
Sulphur " " "	0.06	0.06	0.04
Nickel " " "	....	....	3.75

PHYSICAL PROPERTIES.

Tensile Tests.

3. For car, engine truck, and tender truck axles no tensile test shall be required.

4. The minimum physical qualities required in the two classes of driving wheel axles shall be as follows:

	Driving wheel axles. (Carbon steel.)	Driving wheel axles. (Nickel steel.)
Tensile strength, pounds per square inch.	80,000	80,000
Yield point, pounds per square inch......	40,000	50,000
Elongation, per cent. in two inches......	18	25
Contraction of area per cent.............	..	45

Drop Test.

5. One axle selected from each melt, when tested by the drop test described in paragraph No. 9, shall stand the number of blows at the height specified in the following table without rupture and without exceeding, as the result of the first blow, the deflection given. Any melt failing to meet these requirements will be rejected.

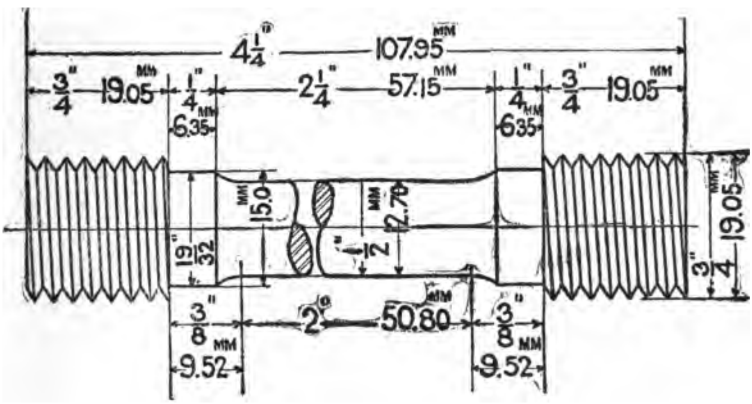
Diameter of axle at center. Inches.	Number of blows.	Height of drop. Feet.	Deflection. Inches.
4 1/4	5	24	8 1/4
4 3/8	5	26	8 1/4
4 7/16	5	28 1/2	8 1/4
4 5/8	5	31	8
4 3/4	5	34	8
5 3/8	5	43	7
5 7/8	7	43	5 1/2

6. Carbon steel and nickel steel driving wheel axles shall not be subject to the above drop test.

Test Pieces and Methods of Testing.

Test Specimen for Tensile Test.

7. The standard turned test specimen one-half inch (1/2″) diameter and two inch (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 4. It is shown in the following sketch:



Number and Location of Tensile Specimens.

8. One longitudinal test specimen shall be cut from one axle of each melt. The center of this test specimen shall be half way between the center and outside of the axle.

Drop Test Described.

9. The points of supports on which the axle rests during tests must be three feet apart from center to center; the tup must weigh 1,640 pounds; the anvil, which is supported on springs, must weigh 17,500 pounds; it must be free to move in a vertical direction; the springs upon which it rests must be twelve in number, of the kind described on drawing; and the radius of supports and of the striking face on the tup in the direction of the axis of the axle must be five (5) inches. When an axle is tested it must be so placed in the machine that the tup will strike it midway between the ends, and it must be turned over after the first and third blows, and when required, after the fifth blow. To measure the deflection after the first blow prepare a straight edge as long as the axle, by reinforcing it on one side,

equally at each end, so that when it is laid on the axle, the reinforced parts will rest on the collars or ends of the axle, and the balance of the straight edge not touch the axle at any place. Next place the axle in position for test, lay the straight edge on it, and measure the distance from the straight edge to the axle at the middle point of the latter. Then after the first blow, place the straight edge on the now bent axle in the same manner as before, and measure the distance from it to that side of the axle next to the straight edge at the point farthest away from the latter. The difference between the two measurements is the deflection.

Yield Point.

10. The yield point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

Sample for Chemical Analysis.

11. Turnings from the tensile test specimen of driving axles, or drillings taken midway between the center and outside of car, engine, and tender truck axles, or drillings from the small test ingot if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

Finish.

12. Axles shall conform in sizes, shapes and limiting weights to the requirements given on the order or print sent with it. They shall be made and finished in a workmanlike manner, and shall be free from all injurious cracks, seams or flaws. In centering, sixty (60) degree centers must be used, with clearance given at the point to avoid dulling the shop lathe centers.

Branding.

13. Each axle shall be legibly stamped with the melt number and initials of the maker at the places marked on the print or indicated by the inspector.

Inspection.

14. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STEEL FORGINGS.

Process of Manufacture.

1. Steel for forgings may be made by the open-hearth, crucible or Bessemer process.

Chemical Properties.

2. There will be four classes of steel forgings which shall conform to the following limits in chemical composition.

	Forgings of soft or low carbon steel.	Forgings of carbon steel not annealed.	Forgings of carbon steel, oil tempered or annealed.	Forgings of nickel steel, oil tempered or annealed.
	Per cent.	Per cent.	Per cent.	Per cent.
Phosphorus shall not exceed...	0.10	0.06	0.04	0.04
Sulphur " ...	0.10	0.06	0.04	0.04
Nickel " ...	——	——	——	3.75

Physical Properties.

3. **Tensile Tests.** The minimum physical qualities required of the different sized forgings of each class shall be as follows:

Tensile strength. Pounds per square inch.	Yield point. Pounds per square inch.	Elongation in 2". Per cent.	Contraction of area. Per cent.	
				SOFT STEEL OR LOW CARBON STEEL.
58,000	29,000	28	35	For solid or hollow forgings, no diameter or thickness of section to exceed 10".
				CARBON STEEL NOT ANNEALED.
75,000	37,500	18	30	For solid or hollow forgings, no diameter or thickness of section to exceed 10".
	Elastic limit.			CARBON STEEL ANNEALED.
80,000	40,000	22	35	For solid or hollow forgings, no diameter or thickness of section to exceed 10".
75,000	37,500	23	35	For solid forgings, no diameter to exceed 20" or thickness of section 15".
70,000	35,000	24	30	For solid forgings, over 20" diameter.
				CARBON STEEL, OIL TEMPERED.
90,000	55,000	20	45	For solid or hollow forgings, no diameter or thickness of section to exceed 3".

Tensile strength.	Elastic Limit.	Elongation in 2".	Contraction of area.	
Pounds per square inch.		Per cent.		
				CARBON STEEL, OIL TEMPERED.
85,000	50,000	22	45	For solid forgings of rectangular sections not exceeding 6" in thickness or hollow forgings, the walls of which do not exceed 6" in thickness.
80,000	45,000	23	40	For solid forgings of rectangular sections not exceeding 10" in thickness or hollow forgings, the walls of which do not exceed 10" in thickness.
				NICKEL STEEL ANNEALED.
80,000	50,000	25	45	For solid or hollow forgings, no diameter or thickness of section to exceed 10".
80,000	45,000	25	45	For solid forgings, no diameter to exceed 20" or thickness of section 15".
80,000	45,000	24	40	For solid forgings, over 20" diameter.
				NICKEL STEEL, OIL TEMPERED.
95,000	65,000	21	50	For solid or hollow forgings, no diameter or thickness of section to exceed 3".
90,000	60,000	22	50	For solid forgings of rectangular sections not exceeding 6" in thickness or hollow forgings, the walls of which do not exceed 6" in thickness.
85,000	55,000	24	45	For solid forgings of rectangular sections not exceeding 10" in thickness or hollow forgings, thewalls of which do not exceed 10" in thickness.

Bending Test.

4. A specimen one inch by one-half inch (1" x 1/2") shall bend cold 180° without fracture on outside of bent portion, as follows:

Around a diameter of 1/2", for forgings of soft steel,

Around a diameter of 1 1/2", for forgings of carbon steel not annealed,

Around a diameter of 1 1/2", for forgings of carbon steel annealed, if 20" in diameter or over,

Around a diameter of 1", for forgings of carbon steel annealed, if under 20" diameter,

Around a diameter of 1" for forgings of carbon steel oil-tempered,

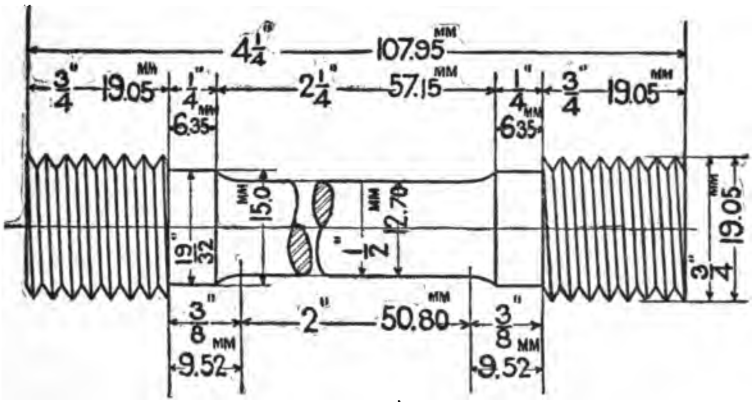
Around a diameter of 1/2", for forgings of nickel steel annealed,

Around a diameter of 1", for forgings of nickel steel oil-tempered.

Test Pieces and Methods of Testing.

Test Specimen for Tensile Test.

5. The standard turned test specimen, one-half inch (1/2″) diameter and two inch (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in the following sketch.



Number and Location of Tensile Specimens.

6. The number and location of test specimens to be taken from a melt, blow, or a forging shall depend upon its character and importance and must therefore be regulated by individual cases. The test specimens shall be cut cold from the forging or full-sized prolongation of same parallel to the axis of the forging and half way between the center and outside, the specimens to be longitudinal, *i. e.*, the length of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, half way between the inner and outer surface of the wall of the forging.

Test Specimen for Bending.

7. The specimen for bending test one inch by one-half inch (1″ x 1/2″) shall be cut as specified in paragraph No. 6. The bending test may be made by pressure or by blows.

8. The yield point specified in paragraph No. 3 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

Yield Point.

9. The elastic limit specified in paragraph No. 3 shall be determined by means of an extensometer, which is to be attached to the test specimen in such manner as to show the change in rate of extension under uniform rate of loading, and will be taken at that point where the proportionality changes.

Elastic Limit.

10. Turnings from the tensile specimen or drillings from the bending specimen or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical composition specified in paragraph No. 2.

Sample for Chemical Analysis.

FINISH.

11. Forgings shall be free from cracks, flaws, seams or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser, and be made and finished in a workmanlike manner.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STEEL TIRES.

PROCESS OF MANUFACTURE.

1. Steel for tires may be made by either the open-hearth or crucible process.

CHEMICAL PROPERTIES.

2. There will be three classes of steel tires which shall conform to the following limits in chemical composition:

	Passenger engines. Per cent.	Freight engine and car wheels. Per cent.	Switching engines. Per cent.
Manganese shall not exceed .	0.80	0.80	0.80
Silicon shall not be less than .	0.20	0.20	0.20
Phosphorus shall not exceed .	0.05	0.05	0.05
Sulphur shall not exceed....	0.05	0.05	0.05

PHYSICAL PROPERTIES.

3. The minimum physical qualities required in each of the three classes of steel tires shall be as follows:

Tensile Tests.

	Passenger engines.	Feight engine and car wheels.	Switching engines.
Tensile strength, pounds per square inch..	100,000	110,000	120,000
Elongation, per cent in two inches........	12	10	8

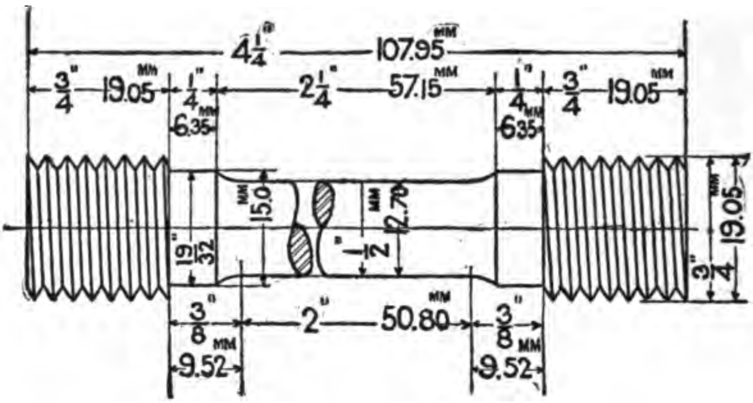
4. In the event of the contract calling for a drop test, a test tire from each melt will be furnished at the purchaser's expense, provided it meets the requirements. This test tire shall stand the drop test described in paragraph No. 7, without breaking or cracking, and shall show a minimum deflection equal to $D^2 \div (40T^2 + 2D)$, the letter "D" being internal diameter and the letter "T" thickness of tire at center of tread.

Drop Test.

TEST PIECES AND METHODS OF TESTING.

5. The standard turned test specimen, one-half inch (1/2") diameter and two inch (2") gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in the following sketch:

Test Specimen for Tensile Tests.



6. When the drop specimen is specified, this test specimen shall be cut cold from the tested tire at the point least affected by the drop test. If the diameter of the tire is such that the whole circumference of the tire is seriously affected by the drop test, or if no drop test is required, the test specimen shall be forged from a test ingot cast when pouring the melt, the test ingot receiving, as nearly as possible, the same proportion of reduction as the ingots from which the tires are made.

Location of Tensile Specimens.

7. The test tire shall be placed vertically under the drop in a running position on a solid foundation of at least ten tons in weight and subjected to successive blows from a tup weighing 2240 pounds, falling from increasing heights until the required deflection is obtained.

Drop Test Described.

8. Turnings from the tensile specimen, or drillings from the small test ingot, or turnings from the tire if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

Sample for Chemical Analysis.

FINISH.

9. All tires shall be free from cracks, flaws, or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser.

Branding.

10. Tires shall be stamped with the maker's brand and number in such a manner that each individual tire may be identified.

Inspection.

11. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STEEL RAILS.

Process of Manufacture.

1. (*a*). Steel may be made by the Bessemer or open-hearth process.

(*b*). The entire process of manufacture and testing shall be in accordance with the best standard current practice, and special care shall be taken to conform to the following instructions.

(*c*). Ingots shall be kept in a vertical position in pit heating furnaces.

(*d*). No bled ingots shall be used.

(*e*). Sufficient material shall be discarded from the top of the ingots to insure sound rails.

Chemical Properties.

2. Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

	50 to 59 + pounds. Per cent.	60 to 69 + pounds. Per cent.	70 to 79 + pounds. Per cent.	80 to 89 + pounds. Per cent.	90 to 100 pounds. Per cent.
Carbon	0.35–0.45	0.38–0.48	0.40–0.50	0.43–0.53	0.45–0.55
Phosphorus shall not exceed ..	0.10	0.10	0.10	0.10	0.10
Silicon shall not exceed	0.20	0.20	0.20	0.20	0.20
Manganese	0.70–1.00	0.70–1.00	0.75–1.05	0.80–1.10	0.80–1.10

Physical Properties.

3. One drop test shall be made on a piece of rail not more than six feet long, selected from every fifth blow of steel. The rail shall be placed head upwards on the supports and the various sections shall be subjected to the following impact tests.

Drop Test.

Weight of rail. Pounds per yard.			Height of drop. Feet.
	45 to and including	55	15
More than	55 "	65	16
"	65 "	75	17
"	75 "	85	18
"	85 "	100	19

If any rail break when subjected to the drop test, two additional tests will be made of other rails from the same blow of steel, and if either of these latter tests fail all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted. If the rails from the tested blow shall be rejected for failure to meet the requirements of the drop test as above specified, two other rails will be subjected to the same tests, one from the blow next preceding, and one from the blow next succeeding the rejected blow. In case the first test taken from the preceding or succeeding blow shall fail, two additional tests shall be taken from the same blow of steel, the acceptance or rejection of which shall also be determined as specified above, and if the rails of the preceding or succeeding blow shall be rejected, similar tests may be taken from the previous or following blows, as the case may be, until the entire group of five blows is tested, if necessary.

The acceptance or rejection of all the rails from any blow will depend upon the result of the tests thereof.

Test Pieces and Methods of Testing.

Drop Testing Machine.

4. The drop test machine shall have a tup of two thousand (2000) pounds weight, the striking face of which shall have a radius of not more than five inches (5″), and the test rail shall be placed head upwards on solid supports three feet (3′) apart. The anvil block shall weigh at least twenty thousand (20,000) pounds, and the supports shall be a part of, or firmly secured to, the anvil.

Sample for Chemical Analysis.

5. The manufacturer shall furnish the inspector, daily, with carbon determinations of each blow, and a complete chemical analysis every twenty-four hours, representing the average of the other elements contained in the steel. These analyses shall be made on drillings taken from a small test ingot.

Finish.

Section.

6. Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad

company, consistent with paragraph No. 7, relative to specified weight. A variation in height of one sixty-fourth of an inch (1/64") less and one thirty-second of an inch (1/32") greater than the specified height will be permitted. A perfect fit of the splice bars, however, shall be maintained at all times.

Weight. 7. The weight of the rails shall be maintained as nearly as possible after complying with paragraph No. 6, to that specified in contract. A variation of one half of one per cent. (1/2%) for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

Length. 8. The standard length of rails shall be thirty feet (30'). Ten per cent. (10%) of the entire order will be accepted in shorter lengths, varying by even feet down to twenty-four feet (24'). A variation of one-fourth of an inch (1/4") in length from that specified will be allowed.

Drilling. 9. Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs.

Finish. 10. Rails shall be straightened while cold, smooth on head, sawed square at ends, and, prior to shipment, shall have the burr, occasioned by the saw cutting, removed, and the ends made clean. Number 1 rails shall be free from injurious defects and flaws of all kinds.

BRANDING.

11. The name of the maker, the month and year of manufacture, shall be rolled in raised letters on the side of the web, and the number of the blow shall be stamped on each rail.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

No. 2 Rails.

13. Rails that possess any injurious physical defects, or which for any other cause are not suitable for first quality, or number 1 rails, shall be considered as number 2 rails, provided, however, that rails which contain any physical defects which seriously impair their strength shall be rejected. The ends of all number 2 rails shall be painted in order to distinguish them.

STEEL SPLICE BARS.

Process of Manufacture.

1. Steel for splice bars may be made by the Bessemer or open-hearth process.

Chemical Properties.

2. Steel for splice bars shall conform to the following limits in chemical composition :

	Per cent.
Carbon shall not exceed..........................	0.15
Phosphorus shall not exceed	0.10
Manganese..	0.30 to 0.60

Physical Properties.

3. Splice bar steel shall conform to the following physical qualities :—

Tensile Tests.

Tensile strength, pounds per square inch......	54,000 to 64,000
Yield point, pounds per square inch..........	32,000
Elongation, per cent. in eight inches shall not be less than	25

4. (*a*) A test specimen cut from the head of the splice bar shall bend 180° flat on itself without fracture on the outside of the bent portion

Bending Tests.

(*b*) If preferred the bending tests may be made on an unpunched splice bar, which, if necessary, shall be first flattened, and shall then be bent 180° flat on itself without fracture on the outside of the bent portion.

Test Pieces and Methods of Testing.

5. A test specimen of eight inch (8″) gauged length, cut from the head of the splice bar, shall be used to determine the physical properties specified in paragraph No. 3.

Test Specimen for Tensile Test

6. One tensile test specimen shall be taken from the rolled splice bars of each blow or melt, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

Number of Tensile Tests.

7. One test specimen cut from the head of the splice bar shall be taken from a rolled bar of each blow or melt, or if preferred the bending test may be made on an unpunched splice bar, which, if necessary, shall be flattened before testing. The bending test may be made by pressure or by blows.

Test Specimen for Bending.

8. For the purposes of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Yield Point.

9. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

Sample for Chemical Analysis.

FINISH.

10. All splice bars shall be smoothly rolled and true to templet. The bars shall be sheared accurately to length and free from fins or cracks, and shall perfectly fit the rails for which they are intended. The punching and notching shall accurately conform in every respect to the drawing and dimensions furnished.

BRANDING.

11. The name of the maker and the year of manufacture shall be rolled in raised letters on the side of the splice bar.

INSPECTION.

12. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer, to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STRUCTURAL STEEL FOR BUILDINGS.

PROCESS OF MANUFACTURE.

1. Steel may be made by either the open-hearth or Bessemer process.

CHEMICAL PROPERTIES.

2. Each of the two classes of structural steel for buildings shall not contain more than 0.10 per cent. of phosphorus.

PHYSICAL PROPERTIES.

Classes.

3. There shall be two classes of structural steel for buildings, namely: RIVET STEEL and MEDIUM STEEL which shall conform to the following physical qualities:

4. **Tensile Tests.**

	Rivet steel.	Medium steel.
Tensile strength, pounds per square inch	50,000 to 60,000	60,000 to 70,000
Yield point, in pounds per square inch shall not be less than.....	30,000	35,000
Elongation, per cent. in eight inches shall not be less than..........	26	22

Modifications in elongation for thin and thick material.

5. For material less than five-sixteenths inch (5/16″), and more than three-fourths inch (3/4″) in thickness, the following modifications shall be made in the requirements for elongation:

(*a*). For each increase of one-eighth inch (1/8″) in thickness above three-fourths inch (3/4″), a deduction of one per cent. (1 %) shall be made from the specified elongation.

(*b*). For each decrease of one-sixteenth inch (1/16″) in thickness below five-sixteenths inch (5/16″) a deduction of two and one-half per cent. (2 1/2%) shall be made from the specified elongation.

(*c*). For pins the required elongation shall be five per cent. (5%) less than that specified in paragraph No. 4, as determined on a test specimen the center of which shall be one inch (1″) from the surface.

Bending Tests.

6. The two classes of structural steel for buildings shall conform to the following bending tests; and for this purpose the test specimen shall be one and one-half inches (1 1/2") wide, if possible, and for all material three-fourths inch (3/4") or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut, but for material more than three-fourths inch (3/4") thick the bending test specimen may be one-half inch (1/2") thick:

Rivet rounds shall be tested of full size as rolled.

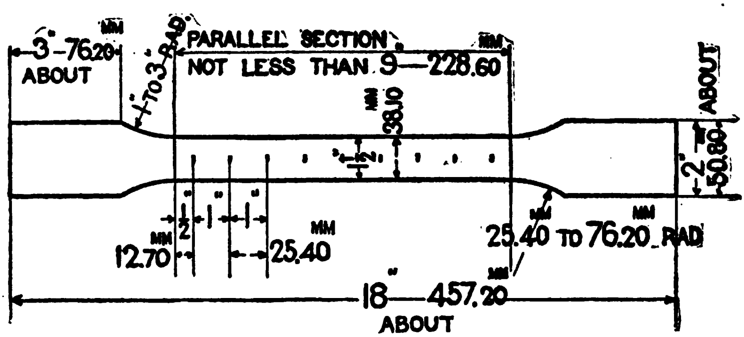
(*d*). Rivet steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*e*). Medium steel shall bend cold 180° around a diameter equal to the thickness of the specimen tested, without fracture on the outside of the bent portion.

Test Pieces and Methods of Testing.

Test Specimen for Tensile Test.

7. The standard test specimen of eight inch (8") gauged length, shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown by the following sketch:



PIECE TO BE OF SAME THICKNESS AS THE PLATE.

For other material the test specimen may be the same as for sheared plates or it may be planed or turned parallel throughout its entire length and in all cases where possible, two opposite sides of the

test specimen shall be the rolled surfaces. Rivet rounds and small rolled bars shall be tested of full size as rolled.

Number of Tensile Tests.

8. One tensile test specimen shall be taken from the finished material of each melt or blow, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

Test Specimen for Bending.

9. One test specimen for bending shall be taken from the finished material of each melt or blow as it comes from the rolls and for material three-fourths inch (3/4") and less in thickness this specimen shall have the natural rolled surface on two opposite sides. The bending test specimen shall be one and one-half inches (1 1/2") wide, if possible, and for material more than three-fourths inch (3/4") thick the bending test specimen may be one-half inch (1/2") thick.

Rivet rounds shall be tested of full size as rolled.

(*f*). The bending test may be made by pressure or by blows.

Annealed Test Specimens.

10. Material which is to be used without annealing or further treatment shall be tested for tensile strength in the condition in which it comes from the rolls. For material which is to be annealed or otherwise treated before use, a full-sized section of tensile test specimen length, shall be similarly treated before cutting the tensile test specimen therefrom.

Yield Point.

11. For the purposes of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Sample for Chemical Analysis.

12. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

VARIATION IN WEIGHT.

13. The variation in cross section or weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*g*). Plates 12 1/2 pounds per square foot or heavier, when ordered to weight, shall not average more than 2 1/2 per cent. variation above or 2 1/2 per cent. below the theoretical weight.

(*h*). Plates under 12 1/2 pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2 1/2 per cent. above or 2 1/2 per cent. below the theoretical weight.

75 inches and over, 5 per cent. above or 5 per cent below the theoretical weight.

(*i*). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

The weight of one cubic inch of rolled steel is assumed to be 0.2833 pound.

Plates 1/4 inch and over in thickness.

Thickness of plate. Inch.	Width of plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
1/4	10	14	18
5/16	8	12	16
3/8	7	10	13
7/16	6	8	10
1/2	5	7	9
9/16	4 1/2	6 1/2	8 1/2
5/8	4	6	8
over 5/8	3 1/2	5	6 1/2

Plates under 1/4 inch in thickness.

Thickness of plate. Inch.	Width of plate. Up to 50 inches. Per cent.	50 inches and above. Per cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

FINISH.

14. Finished material must be free from injurious seams, flaws or cracks, and have a workmanlike finish.

Branding.

15. Every finished piece of steel shall be stamped with the melt or blow number, except that small pieces may be shipped in bundles securely wired together with the melt or blow number on a metal tag attached.

Inspection.

16. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STRUCTURAL STEEL FOR BRIDGES AND SHIPS.

PROCESS OF MANUFACTURE.

1. Steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES.

2. Each of the three classes of structural steel for bridges and ships shall conform to the following limits in chemical composition :

	Steel made by the acid process. Per cent.	Steel made by the basic process. Per cent.
Phosphorus shall not exceed	0.08	0.06
Sulphur shall not exceed	0.06	0.06

PHYSICAL PROPERTIES.

Classes.

3. There shall be three classes of structural steel for bridges and ships, namely : RIVET STEEL, SOFT STEEL, and MEDIUM STEEL, which shall conform to the following physical qualities :

4. **Tensile Tests.**

	Rivet steel.	Soft steel.	Medium steel.
Tensile strength, pounds per square inch	50,000 to 60,000	52,000 to 62,000	60,000 to 70,000
Yield point, in pounds square inch, shall not be less than	30,000	32,000	35,000
Elongation in per cent. eight inches shall not be less than	26	25	22

Modifications in elongation for thin and thick material.

5. For material less than five-sixteenths inch (5/16″), and more than three-fourths inch (3/4″) in thickness, the following modifications shall be made in the requirements for elongation :

(*a*). For each increase of one-eighth inch (1/8″) in thickness above three-fourths inch (3/4″), a deduction of one per cent. (1 %) shall be made from the specified elongation.

(*b*). For each decrease of one-sixteenth inch (1/16″) in thickness below five-sixteenths inch (5/16″), a deduction of two and

one-half per cent. (2 1/2%) shall be made from the specified elongation.

(*c*). For pins made from any of the three classes of steel, the required elongation shall be five per cent. (5%) less than that specified in paragraph No. 4, as determined on a test specimen the center of which shall be one inch (1″) from the surface.

Tensile Tests of Eye-bars.

6. Eye-bars shall be of medium steel. Full-sized tests shall show 12 1/2 per cent. elongation in fifteen feet of the body of the eye-bar, and the tensile strength shall not be less than 55,000 pounds per square inch. Eye-bars shall be required to break in the body, but should an eye-bar break in the head, and show twelve and one-half percent (12 1/2%) elongation in fifteen feet and the tensile strength specified, it shall not be cause for rejection, provided that not more than one-third (1/3) of the total number of eye-bars tested break in the head.

Bending Tests

7. The three classes of structural steel for bridges and ships shall conform to the following bending tests; and for this purpose the test specimen shall be one and one-half inches wide, if possible, and for all material three-fourths inch (3/4″) or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut, but for material more than three-fourths inch (3/4″) thick the bending test specimen may be one-half inch (1/2″) thick:

Rivet rounds shall be tested of full size as rolled.

(*d*). Rivet steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

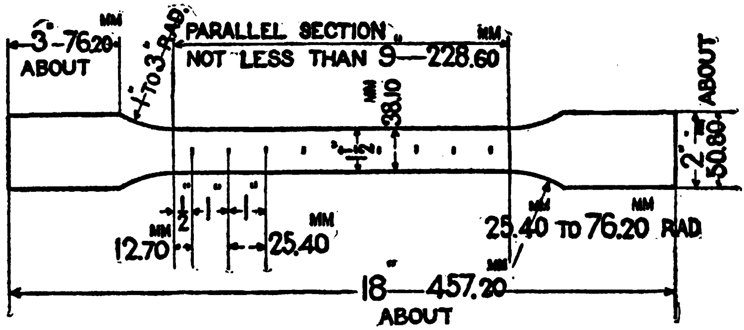
(*e*). Soft steel shall bend cold 180° flat on itself without fracture on the outside of the bent portion.

(*f*). Medium steel shall bend cold 180° around a diameter equal to the thickness of the specimen tested, without fracture on the outside of the bent portion.

Test Pieces and Methods of Testing.

Test Specimen for Tensile Test.

8. The standard test specimen of eight inch (8″) gauged length, shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown by the following sketch:



PIECE TO BE OF SAME THICKNESS AS THE PLATE.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length and in all cases where possible, two opposite sides of the test specimens shall be the rolled surfaces. Rivet rounds and small rolled bars shall be tested of full size as rolled.

Number of Tensile Tests.

9. One tensile test specimen shall be taken from the finished material of each melt, but in case this develops flaws, or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

Test Specimens for Bending.

10. One test specimen for bending shall be taken from the finished material of each melt as it comes from the rolls, and for material three-fourths inch (3/4") and less in thickness this specimen shall have the natural rolled surface on two opposite sides. The bending test specimen shall be one and one-half inches (1 1/2") wide, if possible, and for material more than three-fourths inch (3/4") thick the bending test specimen may be one-half inch (1/2") thick.

(*g*). The bending test may be made by pressure or by blows.

Annealed Test Specimens.

11. Material which is to be used without annealing or further treatment shall be tested for tensile strength in the condition in which it comes from the rolls. For material which is to be annealed or otherwise treated before use, a full-sized section of tensile test specimen length, shall be similarly treated before cutting the tensile test specimen therefrom.

Yield Point. 12. For the purpose of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Sample for Chemical Analysis. 13. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot.

VARIATION IN WEIGHT.

14. The variation in cross section or weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*h*). Plates 12 1/2 pounds per square foot or heavier, when ordered to weight, shall not average more than 2 1/2 per cent. variation above or 2 1/2 per cent. below the theoretical weight.

(*i*). Plates under 12 1/2 pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2 1/2 per cent. above or 2 1/2 per cent. below the theoretical weight.

75 inches and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(*j*). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

Plate 1/4 inch and over in thickness.

Thickness of plate. Inch.	Width of plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
1/4	10	14	18
5/16	8	12	16
3/8	7	10	13
7/16	6	8	10
1/2	5	7	9
9/16	4 1/2	6 1/2	8 1/2
5/8	4	6	8
Over 5/8	3 1/2	5	6 1/2

Plates under 1/4 inch in thickness.

Thickness of plate.	Width of plate.	
	Up to 50 inches.	50 inches and above.
Inch.	Per cent.	Per cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

Finish.

15. Finished material must be free from injurious seams, flaws or cracks, and have a workmanlike finish.

Branding.

16. Every finished piece of steel shall be stamped with the melt number, and steel for pins shall have the melt number stamped on the ends. Rivets and lacing steel, and small pieces for pin plates and stiffeners, may be shipped in bundles, securely wired together, with the melt number on a metal tag attached.

Inspection.

17. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

OPEN-HEARTH BOILER PLATE AND RIVET STEEL.

Process of Manufacture.

1. Steel shall be made by the open-hearth process.

Chemical Properties.

2. There shall be three classes of open-hearth boiler plate and rivet steel, namely: FLANGE OR BOILER STEEL, FIRE BOX STEEL and EXTRA SOFT STEEL, which shall conform to the following limits in chemical composition:

	Flange or boiler steel. Per cent.	Fire box steel. Per cent.	Extra soft steel. Per cent.
Phosphorus shall not exceed	0.06	0.04	0.04
Sulphur shall not exceed	0.05	0.04	0.04
Manganese	0.30 to 0.60	0.30 to 0.50	0.30 to 0.50

3. Steel for boiler rivets shall be of the EXTRA SOFT class as specified in paragraphs Nos. 2 and 4.

Boiler Rivet Steel.

Physical Properties.

4. The three classes of open-hearth boiler plate and rivet steel, namely: FLANGE OR BOILER STEEL, FIRE BOX STEEL and EXTRA SOFT STEEL, shall conform to the following physical qualities:

Tensile Tests.

	Flange or boiler steel.	Fire box steel.	Extra soft steel.
Tensile strength, pounds per square inch	55,000 to 65,000	52,000 to 62,000	45,000 to 55,000
Yield point in pounds per square inch shall not be less than	33,000	32,000	30,000
Elongation, per cent. in eight inches shall not be less than	25	26	28

5. For material less than five-sixteenths inch (5/16"), and more than three-fourths inch (3/4") in thickness, the following modifications shall be made in the requirements for elongation:

Modifications in elongation for thin and thick material.

(*a*). For each increase of one-eighth inch (1/8"), in thickness above three-fourths inch (3/4"), a deduction of one per cent. (1%) shall be made from the specified elongation.

(*b*). For each decrease of one-sixteenth inch (1/16″) in thickness below five-sixteenths inch (5/16″) a deduction of two and one-half per cent. (2 1/2%) shall be made from the specified elongation.

6. The three classes of open-hearth boiler plate and rivet steel shall conform to the following bending tests; and for this purpose the test specimen shall be one and one-half inches (1 1/2″) wide if possible, and for all material three-fourths inch (3/4″) or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut; but for material more than three-fourths inch (3/4″) thick, the bending test specimen may be one-half inch (1/2″) thick:

Bending Tests.

Rivet rounds shall be tested of full size as rolled.

(*c*). Test specimens cut from the rolled material as specified above, shall be subjected to a cold bending test, and also to a quenched bending test. The cold bending test shall be made on the material in the condition in which it is to be used, and prior to the quenched bending test, the specimen shall be heated to a light cherry-red as seen in the dark and quenched in water, the temperature of which is between 80° and 90° Fahrenheit.

(*d*). Flange or boiler steel, fire box steel and rivet steel, both before and after quenching, shall bend cold one hundred and eighty degrees (180°) flat on itself without fracture on the outside of the bent portion.

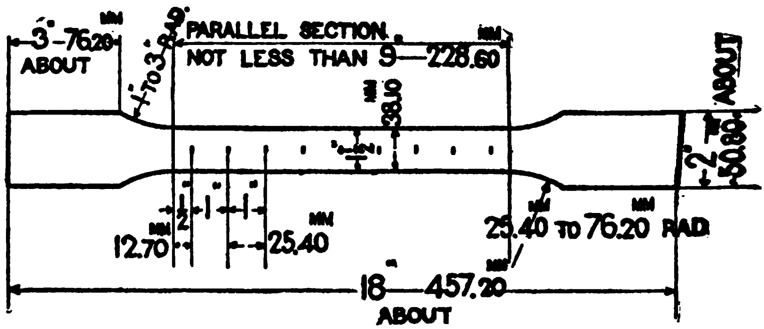
7. For fire box steel a sample taken from a broken tensile test specimen, shall not show any single seam or cavity more than one-fourth inch (1/4″) long in either of the three fractures obtained on the test for homogeneity as described below in paragraph 12.

Homogeneity Tests.

TEST PIECES AND METHODS OF TESTING.

8. The standard test specimen of eight inch (8″) gauged length, shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown by the following sketch:

Test Specimen for Tensile Test.



PIECE TO BE OF SAME THICKNESS AS THE PLATE.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length and in all cases where possible, two opposite sides of the test specimens shall be the rolled surfaces. Rivet rounds and small rolled bars shall be tested of full size as rolled.

Number of Tensile Tests.

9. One tensile test specimen will be furnished from each plate as it is rolled, and two tensile test specimens will be furnished from each melt of rivet rounds. In case any one of these develops flaws or breaks outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor.

Test Specimens for Bending.

10. For material three-fourths inch (3/4") or less in thickness, the bending test specimen shall have the natural rolled surfaces on two opposite sides. The bending test specimens cut from plates shall be one and one-half inches (1 1/2") wide and for material more than three-fourths inch (3/4") thick the bending test specimens may be one-half inch (1/2") thick. The bending test specimens for rivet rounds shall be of full size as rolled. The bending test may be made by pressure or by blows.

Number of Bending Tests.

11. One cold bending specimen and one quenched bending specimen will be furnished from each plate as it is rolled. Two cold bending specimens and two quenched bending specimens will be furnished from each melt of rivet rounds. The homogeneity test for fire box steel shall be made on one of the broken tensile test specimens.

12. The homogeneity test for fire box steel is made as follows: A portion of the broken tensile test specimen is either nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch (1/16″) deep, in three places about two inches (2″) apart. The first groove should be made on one side, two inches (2″) from the square end of the specimen; the second, two inches (2″) from it on the opposite side; and the third, two inches (2″) from the last, and on the opposite side from it. The test specimen is then put in a vise, with the first groove about a quarter of an inch (1/4″) above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken at the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas bubbles in the ingot. After rupture, one side of each fracture is examined, a pocket lens being used if necessary, and the length of the seams and cavities is determined.

Homogeneity Tests for Fire Box Steel.

13. For the purposes of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Yield Point

14. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot. An additional check analysis may be made from a tensile specimen of each melt used on an order, other than in locomotive fire-box steel. In the case of locomotive fire-box steel a check analysis may be made from the tensile specimen from each plate as rolled.

Sample for Chemical Analysis.

Variation in Weight.

15. The variation in cross section or weight of more than 2 1/2 per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*e*). Plates 12 1/2 pounds per square foot or heavier, when ordered to weight, shall not average more than 2 1/2 per cent. variation above, or 2 1/2 per cent. below the theoretical weight.

(*f*). Plates under 12 1/2 pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2 1/2 per cent. above or 2 1/2 per cent. below the theoretical weight.

75 inches and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(*g*). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

Plates 1/4 inch and over in thickness.

Thickness of plate. Inch.	Width of plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
1/4	10	14	18
5/16	8	12	16
3/8	7	10	13
7/16	6	8	10
1/2	5	7	9
9/16	4 1/2	6 1/2	8 1/2
5/8	4	6	8
Over 5/8	3 1/2	5	6 1/2

Plates under 1/4 inch in thickness.

Thickness of plate. Inch.	Width of plate. Up to 50 inches. Per cent.	50 inches and above. Per cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

FINISH.

16. All finished material shall be free from injurious surface defects and laminations, and must have a workmanlike finish.

Branding.

17. Every finished piece of steel shall be stamped with the melt number, and each plate, and the coupon or test specimen cut from it, shall be stamped with a separate identifying mark or number. Rivet steel may be shipped in bundles securely wired together with the melt number on a metal tag attached.

Inspection.

18. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

WROUGHT IRON.

PROCESS OF MANUFACTURE.

1. Wrought iron shall be made by the puddling process or rolled from fagots or piles made up from No. 1 wrought iron scrap, alone or with muck bar added, it being understood that test iron Class B, and stay-bolt iron contain no scrap.

PHYSICAL PROPERTIES.

2. The minimum physical qualities required in the four classes

Tensile Test. of wrought iron shall be as follows:

	Refined iron.	Test iron Class A.	Test iron Class B.	Stay-bolt iron.
Tensile strength, pounds per sq. inch........	48,000	48,000	50,000	46,000
Yield point, pounds per sq. inch............	25,000	25,000	25,000	25,000
Elongation, per cent. in 8 inches............	15	20	25	28

3. In sections weighing less than 0.654 pound per lineal foot the percentage of elongation required in the four classes specified in paragraph No. 2 shall be 11.25 per cent., 15.00 per cent., 18.75 per cent., and 21.00 per cent. respectively.

4. The four classes of iron when nicked and tested as described

Nicking Test. in paragraph No. 9 shall show the following fracture:

(*a*). Refined iron, a generally fibrous fracture, free from coarse crystalline spots. Not over 15 per cent. of the fractured surface shall be granular.

(*b*). Test iron Class A, a generally fibrous fracture, free from coarse crystalline spots. Not over 10 per cent. of the fractured surface shall be granular.

(*c*). Test iron Class B, a long, clean, silky fiber, free from slag or dirt or any coarse crystalline spots. A few fine crystalline spots may be tolerated provided they do not in the aggregate exceed 10 per cent. of the sectional area of the bar.

(*a*). Stay-bolt iron, a long, clean, silky fiber, free from slag or dirt, and wholly fibrous, being practically free from crystalline spots.

5. The four classes of iron when tested as described in paragraph No. 10 shall conform to the following bending tests:

Cold Bending Test.

(*e*). Refined iron shall bend cold 180° around a diameter equal to twice the thickness of the specimen tested, without fracture on outside of the bent portion.

(*f*). Test iron Class A, shall bend cold 180° around a diameter equal to the thickness of the tested specimen, without fracture on outside of the bent portion.

(*g*). Test iron Class B, shall bend cold 180° flat on itself without fracture on outside of the bent portion.

(*h*). Stay-bolt iron, a piece of stay-bolt iron about 24″ long shall bend in the middle through 180° flat on itself, and then bend in the middle through 180° flat on itself in a plane at a right angle to the former direction, without a fracture on outside of the bent portions. Another specimen with a thread cut over the entire length shall stand this double bending without showing deep cracks in the threads.

6. The four classes of iron when tested as described in paragraph No. 11 shall conform to the following hot bending tests:

Hot Bending Test.

(*i*). Refined iron, shall bend sharply to a right angle, without showing cracks or flaws.

(*j*). Test iron Class A, shall bend through 180° flat on itself, without showing cracks or flaws.

(*k*). Test iron Class B, shall bend through 180° flat on itself, without showing cracks or flaws. A similar specimen heated to a yellow heat and suddenly quenched in water between 80° and 90° F. shall bend, without hammering on the bend, 180° flat on itself without showing cracks or flaws. A similar specimen heated to a bright red heat shall be split at the end and each part bent back through an angle of 180°. It will also be punched and expanded by drifts until a round hole is formed whose diameter is not less than nine-tenths of the diameter of the rod or width of the bar. Any extension of the original split or indications of fracture, cracks, or flaws developed by the above tests will be

sufficient cause for the rejection of the lot represented by that rod or bar.

(*l*). Stay-bolt iron, shall bend through 180° flat on itself, without showing cracks or flaws. A similar specimen heated to a yellow heat and suddenly quenched in water between 80° and 90° F. shall bend, without hammering on the bend, 180° flat on itself without showing cracks or flaws.

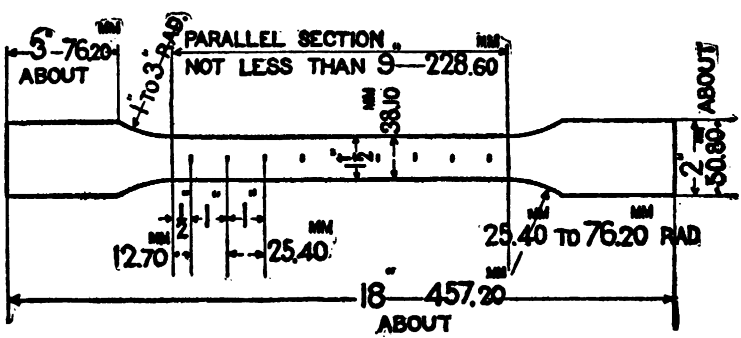
Threading Test.

7. Stay-bolt iron shall permit of the cutting of a clean sharp thread and be rolled true to gauges desired, so as not to jam in the threading dies.

TEST PIECES AND METHODS OF TESTING.

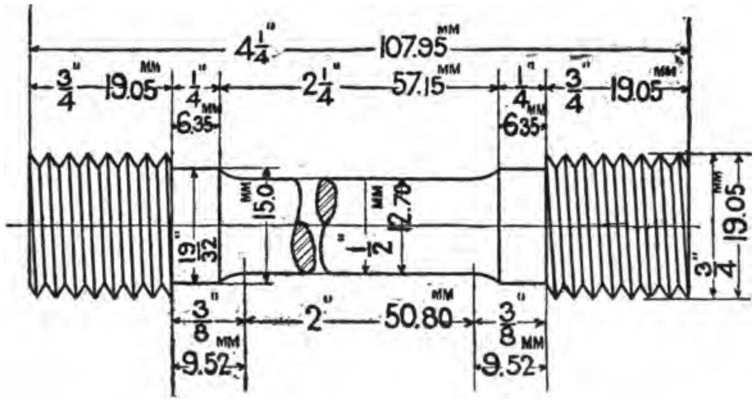
Test Specimen for Tensile Test.

8. Whenever possible iron shall be tested in full size as rolled, to determine the physical qualities specified in paragraphs Nos. 2 and 3, the elongation being measured on an eight inch (8″) gauged length. In flats and shapes too large to test as rolled, the standard test specimen one and one-half inches (1 1/2″) wide and eight inch (8″) gauged length. In large rounds the standard test specimen of two inch (2″) gauged length shall be used; the center of this specimen shall be half way between the center and outside of the round. Sketches of these two standard test specimens are as follows:



PIECE TO BE OF SAME THICKNESS AS THE PLATE.

9. Nicking tests shall be made on specimens cut from the iron as rolled. The specimen shall be slightly and evenly nicked on



Nicking Tests.

one side and bent back at this point through an angle of 180° by a succession of light blows. Tested iron Class B, and stay-bolt iron may be nicked approximately 20 per cent. of its thickness.

Cold Bending Tests.

10. Cold bending tests shall be made on specimens cut from the bar as rolled. The specimen shall be bent through an angle of 180° by pressure or by a succession of light blows.

Hot Bending Tests.

11. Hot bending tests shall be made on specimens cut from the bar as rolled. The specimens, heated to a bright red heat, shall be bent through an angle of 180° by pressure or by a succession of light blows and without hammering directly on the bend.

If desired a similar bar of any of the four classes of iron shall be worked and welded in the ordinary manner without showing signs of red shortness.

Yield Point.

12. The yield point specified in paragraph No. 2 shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Finish.

13. All wrought iron must be practically straight, smooth, free from cinder spots or injurious flaws, buckles, blisters or cracks.

As the thickness of bars approaches the maximum that the rolls will produce the same perfection of finish will not be required as in thinner ones.

In flat and square bars one thirty-second of an inch (1/32″) variation either way from the size ordered will be allowed.

In round iron one one-hundredth of an inch (1/100″) variation either way from the size ordered will be allowed, except in stay-bolt iron which shall be at least one one-hundredth of an inch (1/100″) and not more than twenty-five thousandths of an inch (25/1000″) below normal size, to insure freedom from jamming in the threading dies.

Inspection.

14. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.